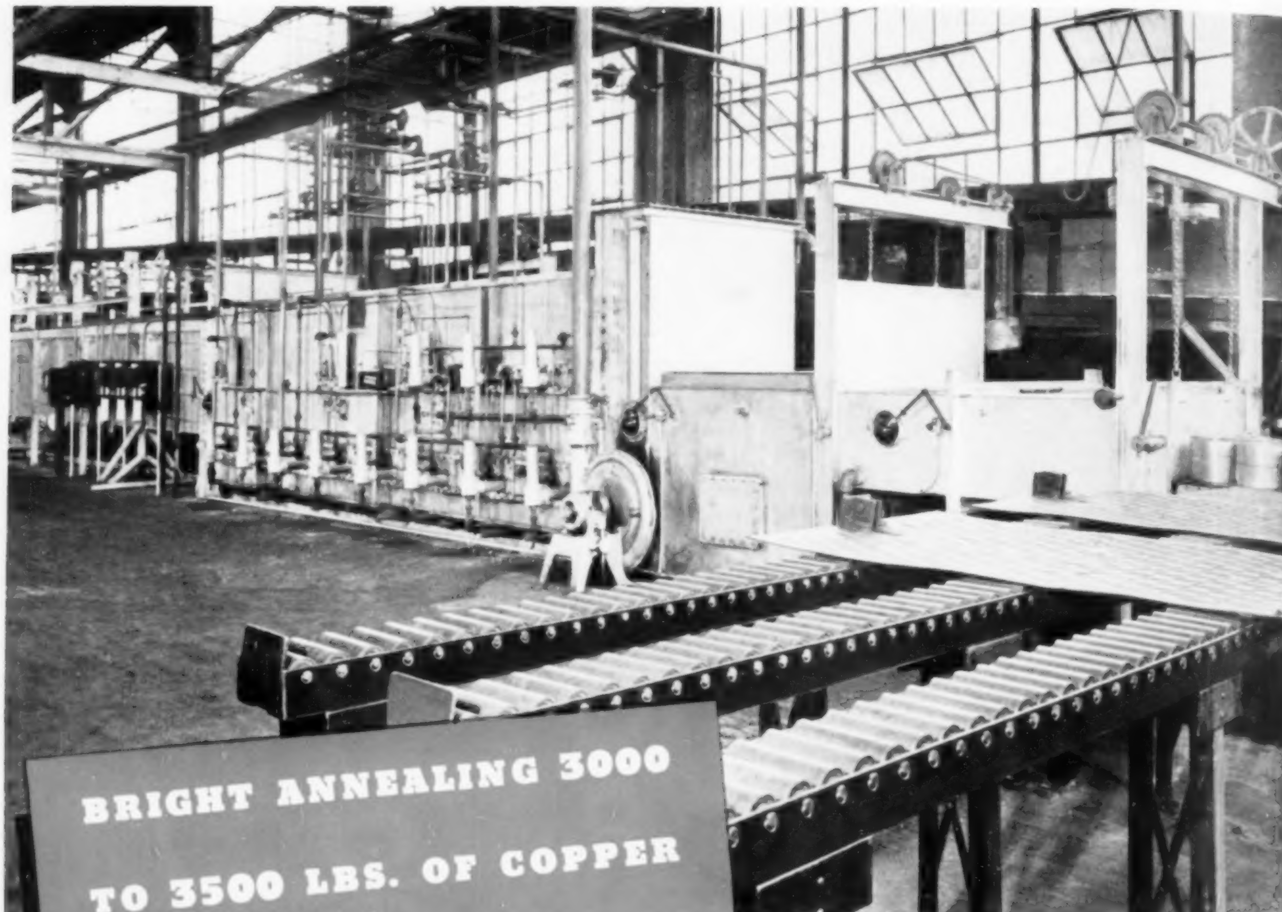
METAL PROGRESS

JUNE 1936

A DETAIL FROM A STAINLESS STEEL DOOR BY OSCAR BACH, PHOTOGRAPHED ON PAGE 36



BRIGHT ANNEALING 3000 TO 3500 LBS. OF COPPER STRIP PER HOUR AT 800° F. IN CONTROLLED ATMOSPHERE

SC Gas-Fired Controlled Atmosphere Bright Annealing Furnace, with SC Radiant Heating Elements, an outstanding SC Development.

● Demand on the part of users of non-ferrous metals for clean material, free from oxide and discoloration, has led to the general practice of bright annealing. For this purpose there is scarcely a large producer who does not have one or more installations of SC equipment. Proven new developments in bright annealing cut costs, speed production, produce superior quality work.

Typical is the installation pictured, which bright anneals 3000 to 3500 lbs. of coiled copper strip per hour, at 800° F., in controlled atmosphere, with a gas consumption of only .677 cu. ft. of 530 BTU city gas per hour. Heating is accomplished by SC Gas-Fired Radiant Heating Elements, mounted above and below the conveyor along which the copper strip in coils passes in perforated alloy trays. The material is cooled in a cooling chamber to 150° F. before being discharged. A specially prepared gas mixture is maintained in both the heating and cooling chambers by means of an SC DX Gas Preparation Unit, which prevents oxidization and discoloration. Heat seals prevent air infiltration at charge and discharge ends of the furnace.

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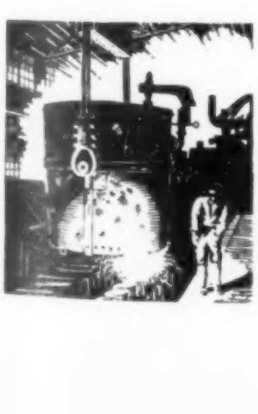
METAL PROGRESS

Vol. 29 *June, 1936* *No. 6*

Matter About Stainless Steel

Other Features



METAL PROGRESS

Vol. 29 *June, 1936* *No. 6*

The Future of Stainless

An Editorial

Stainless steel has shot up like a meteor on the metallurgical horizon. While it was discovered in England before the War, the rapid commercial development has occurred in America within the last ten years. Stainless steel is even yet very much of a specialty. The question therefore arises, "What are the logical developments in the future?"

From a tonnage standpoint the amount produced in America is not impressive compared with the total steel production or even the total alloy steel production. Nevertheless, statistics gathered by E. F. Cone indicate that the trend is rapidly forward. He finds that in 1929 about 40,000 tons of ingots classified as one or another of the stainless steels were cast and processed into rolled products. Production reached bottom in the 1932 depression year (22,600 tons) but in 1934 had bounded back up to about 75,000 tons. A reasonable guess is that 1935 production was even larger and that 100,000 tons will be exceeded in 1936. This will sell for $50,000,000, a tidy sum! These figures reveal great progress in comparison with the unsatisfactory trend of our heavy steel industry since 1929.

In fact, it has been amazing when prices are considered. Soft steel bars carry a base price of about 2¢ per lb.; the engineering alloy steels 6¢, more or less, but 18-8 stainless steel bars sell for 23¢ per lb. base. This is the highest priced steel on the market, except high speed tool steel (55¢ base price for 18-4-1 bars). Stainless sheet and strip with special treatment and finishes may even approach that dizzy price level.

It is apparent that the future expansion of those uses well established at present into real tonnage outlets will hinge on the question of price. Several factors come in here, among which may be mentioned cost of raw materials, steel mill costs, cost of selling and development costs. Royalties on patented analyses have sometimes been blamed for high prices, but these charges on the standardized grades and types are now by no means excessive.

Alloy costs are undoubtedly high. Low carbon ferrochrome is quoted at 20¢ per lb. of contained chromium and electrolytic nickel at 36¢ per lb. One readily figures about 8¢ for alloy in a pound of 18-8 in the ingot, allowing for slag losses of chromium during melting. As pointed out by our German correspondents in this issue, the steel makers can do little about this other than attempt to develop lower alloys suitable for certain applications. Thus 16% chromium, 6% nickel, 4% manganese alloy is already in production and has the the proper properties for most automotive uses. The English also use much 18% chromium, 2% nickel alloy. Complete replacement of nickel with manganese, such as 20% chromium, 10% manganese, with or without copper, has already been proposed; rather extensive studies indicate a family of alloys of great promise.

Substitutes for chromium are missing, although both aluminum and silicon have the property of ennobling iron. However, if too much chromium is replaced by them some very difficult manufacturing problems arise. Likewise some earnest efforts have been made to make low carbon stainless from cheaper, high carbon ferrochrome or even from chrome ore.

Eventual success in replacing much of the chromium and nickel in the alloys might be responsible for a saving of 1 or 2¢ in raw material costs in the ingot, which, while not much, is some-

thing. At any rate, alloy costs will always remain comparatively high.

Alexander L. Feild has summarized the items responsible for high mill costs in his chapter in The Book of Stainless Steels. These start in with the high temperatures and long times required in electric furnace refining, the excessive proportion of scrap in making a superfine product, the losses and difficulties in remelting this scrap, and the extraordinary costs in finishing the mirror-like surfaces required by many purchasers. As volume of production increases, these items will undoubtedly decrease in importance. The greatest single charge is the cost of a lustrous finish on sheet and strip. Many times this cost could be saved wherever durability rather than beauty is the prime requirement. Material ordered in the as-rolled condition would in those instances save as much as 10¢ a pound.

Selling costs: Stainless steel is sold on a tool steel basis — that is, a salesman may make a special trip and return with an order for a few hundred pounds! So many of these orders are trial orders that the metallurgical service now expected by the purchaser, amounts to over 1¢ per lb. on all sales. Warehousing, packing and shipping costs are also proportionately high when a large number of sizes, shapes and finishes must be carried to furnish customers job lots of this, that or the other composition or modification. Obviously, when consumers are educated about how to handle these new steels successfully, and when they buy them in larger quantities to definite specifications, the selling costs will take a sharp drop.

Closely allied with the above are the development costs. Many new alloys are promoted purely for competitive purposes; on the other hand, many are invaluable in special applications. So many people have become interested that the commercial situation has become exceedingly complex. The Book of Stainless Steels has an index of trade names dated June, 1934, which contains no less than 1250 listings under 342 chemical classifications, the product of 104 manufacturers. In such a commercial situation in a young branch of the industry, it is almost impossible to separate engineer's facts from salesman's propaganda.

Too wide a variety of trade-named alloys is wasteful in many ways. Of course, some chemical variations are necessary, even in a single type, to fit the metal for various processing (cold rolling, piercing, welding, and casting) or for exposure to various corrosive media, but the too frequent arrival of new members of the family is to be deplored. A good alloy requires about two years to develop in the laboratory if its scale, corrosion, and creep resistance is to be investigated, and then another two or three years are necessary to prove it in actual practice. Eventually the customer must pay for this. Sometimes it is worth it; sometimes it is not. Fortunately many of the useless variations on the market have had very little real money spent on them except for ballyhoo.

This rather long discussion is warranted by the present importance of the cost factor. The high cost of the stainless alloys undoubtedly restricts sharply their wider use. Cheaper metals get by. Most applications in the automotive industry, for instance, are decorative. If it is cheaper to stamp parts from brass or soft steel or make die castings, and then put a chromium plate on them that will last for two or three years, than it is to make the parts of paper-thin stainless, the plated ware gets the order. It is to be noted, however, that wherever the bright work is constantly under the driver's eye — as in a banjo-type steering wheel or in a hinge on the engine hood — *stainless* is the rule.

That is the hope of the future. As buyers are educated, they will conclude that in more and more places it is safer not to gamble on substitutes, but to pay the price for the solid article and buy satisfaction. As volume goes up and time goes by, most of the cost items analyzed above will be favorably affected. Raw material and processing costs will shrink; promotional and selling costs will be absorbed. Lower selling prices in turn will open up wider markets, thus starting a favorable cycle whose end can only be guessed at.

* * *

All the above relates to the expanded uses in fields already known to stainless. One should emphasize that one extremely valuable property of the high chromium steels has not been exploited to any great extent — namely, its ability to be heat treated to very high strengths. Speaking generally, it is true that nearly all the stainless steels in use are dead soft annealed; if hardness is desired they are cold rolled or wire drawn. The hardening capacity of the chromium alloy has so far been neglected, and the user has paid dearly for expensive alloy, far heavier than need be to carry the loads.

Of course, it is easier to fabricate soft steels. But if the user had looked for the easiest way

out, the present extensive group of S.A.E. steels would never have been developed. Everyone will admit that it is rarely economical to use an alloy steel of this sort in the as-rolled or annealed condition; the extra raw material cost, however, can easily be recovered in an important axle or gear when the inherent properties of the material are developed by correct heat treatment. How strange it is, then, that in the family of stainless steels, many times as high in alloy content and cost, the possibility of enhancing their mechanical properties and saving in over-all weight has seldom been achieved!

Possibly this is because the user is still hypnotized with the unique property of corrosion resistance; he should be taught that these steels can be magnificently strong as well as enduring. Possibly he has recoiled from the difficulty of adequately heat treating large or complicated structures; so much the worse for our present methods of fabrication and heat treatment — they are in for a thorough revision. For eventually we will get strength as well as durability from these new alloys — a matter which will profit and satisfy both producer and user.

* * *

Some speculations as to the possibility of new varieties of stainless steel may be interesting.

The recent discovery of the combined action of nitrogen and carbon in strengthening and toughening the high chromium-iron alloys is of first importance. It leads one to hope that the chromium-irons can be usefully alloyed with boron (a chemical element nearby carbon in the periodic table). The result should not be a mere substitute for something we now have, but another family of alloys of unique properties — perhaps of that desired family of stainless alloy which can be worked and fabricated in the soft state, and then hardened and strengthened as a whole structure either by mere age or by a mild heating.

The metallurgical theory for this process of precipitation hardening is well known and applied to many other alloys, some of them of excessive hardness and strength. By this means will eventually be found the alloys for high pressure containers (and bolts) to operate at temperatures upwards of 1500° F. — alloys at present wanted by the chemical, petroleum and power industries, but not yet available.

Perhaps we already have had one such high chromium alloy for a long time, but have not brought it under control. F. B. Foley published data in the last issue of METAL PROGRESS on an old valve steel alloy containing about 10.5% Cr, 0.50% C, 1.5% each of Ni and Al. Apparently the nickel and aluminum form an intermetallic compound which is fairly soluble in the austenite at 1600° F., and can be kept in solution by air cooling. Reheating later at 1000° F. precipitates a cloud of the NiAl particles through the metallic crystals and the alloy achieves a strength of 180,000 psi. with 20% elongation.

Other intermetallic compounds of chromium are also known but unfortunately they precipitate from solution at the grain boundaries and embrittle the alloy rather than strengthen it. Maybe this habit can be corrected, when we know more metallurgy.

Another thing we would like, and probably will get, is an 18-8 or equivalent austenitic alloy which will have a very high elastic limit and proof stress when severely cold worked for high ultimate strength. This will be hailed by aeronautic designers and chemical engineers.

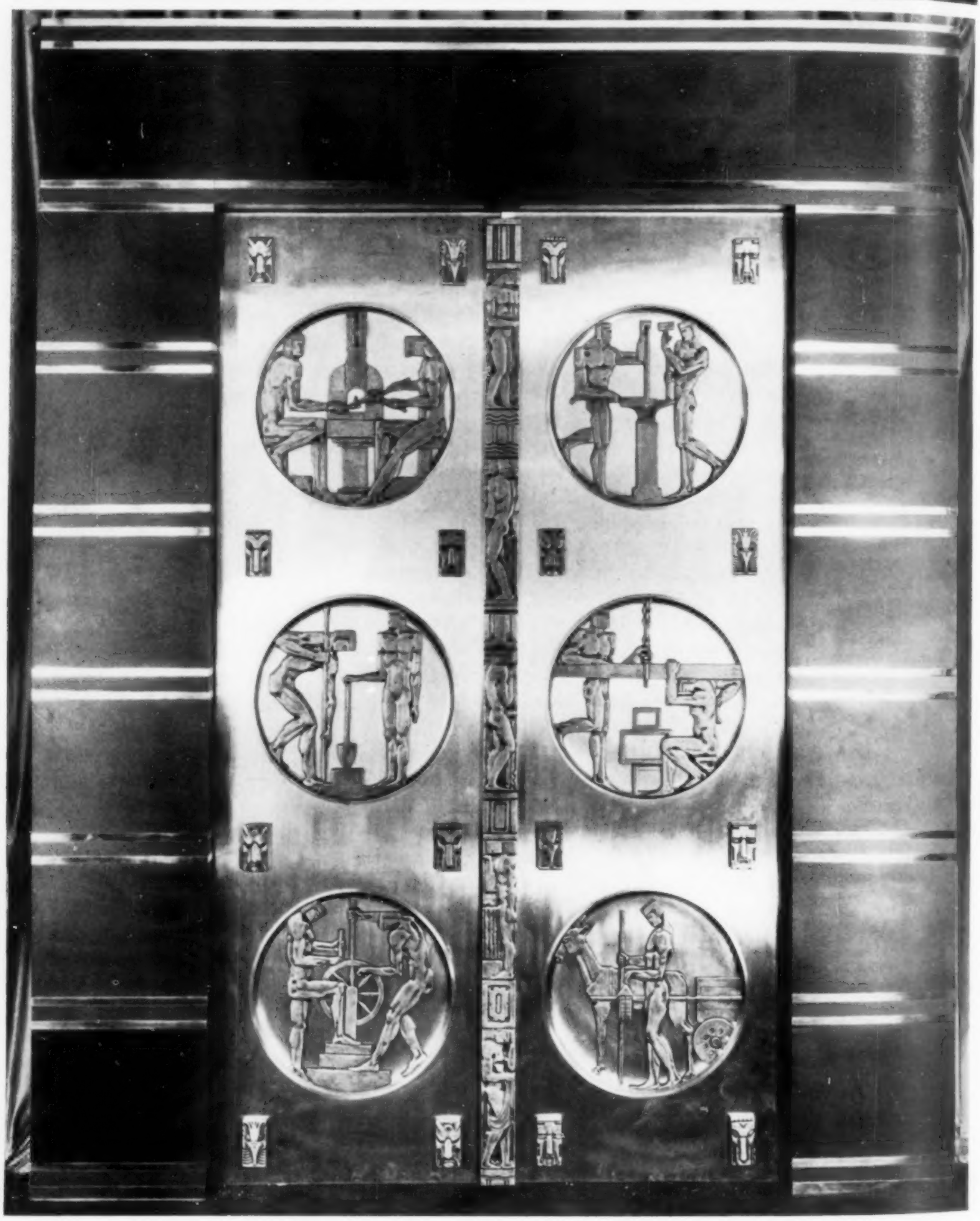
And finally, how about an alloy which will not heat tint at oven temperatures? Think of stainless steel baking dishes and roasting pans that stay bright!

Qualitative Spectrographic Analysis

AN EDITORIAL note captioned "You Are Missing Nothing" was printed in the March issue, commenting on an offer to make a qualitative analysis and rough quantitative estimate of all the metals (70 in all) in any sample for \$6.00. Evidently that editorial was poorly written, for several communications have been received from friends on the West Coast saying that it reflects on the integrity and character of a respected member of the chemical profession.

Certainly nothing of the kind was intended, and the Editor regrets that it has been so interpreted. The object was to call attention to what appears to be unprofitable — namely, to furnish a complete and accurate analysis for \$6.00.

However, it is possible that we are not well informed, and that new equipment has been developed which will revolutionize spectrographic analysis. Consequently the Editor has tendered the Los Angeles assayer who made the offer space comparable to that used in the original editorial to present his views or outline his analytical methods, and sufficient additional space to the manufacturer of his spectrographic equipment for an article describing its construction and operation.



Doors for an Entrance to a Building Devoted to Industry, Designed and Executed by Oscar B. Bach

Plaques Represent Mining, Smelting, Fabrication, Machining, Building and Transportation. The color scheme may be appraised by a glance at the front cover, which utilizes some of the details of this door. The broad, silvery expanse is framed in glazed black sheets, the joints in which are marked with bands of stainless steel colored red and double ribbons of bright steel

An interview with Oscar B. Bach, leading American artist and artificer in decorative metal work, who finds in stainless steel a medium unexcelled for his creative work of enduring beauty

Stainless Steel as a Medium for Artists

"About a decade ago a new metal or a new combination of metals was created which I consider the most remarkable material ever made available for use in exterior and interior architectural facades. It is stainless steel.

"Other materials — stone, marble, terra cotta, tile, bronze, iron, lead and zinc — have left their marks on respective periods in our civilization. So will this new material set its everlasting mark on our century and future civilization.

"Just as we look back at the old times and modes of construction with their stone walls and wonder at the progress that has since been made in steel skeleton building construction and its mechanical wonders, so will generations to come look back upon the construction of the coming era and marvel at the innovations that stainless steel made possible.

"Stainless steels bring to the arts and sciences an entirely new medium of expression — whether for artistic purposes or for the almost limitless utilitarian uses where a permanent metal is needed."

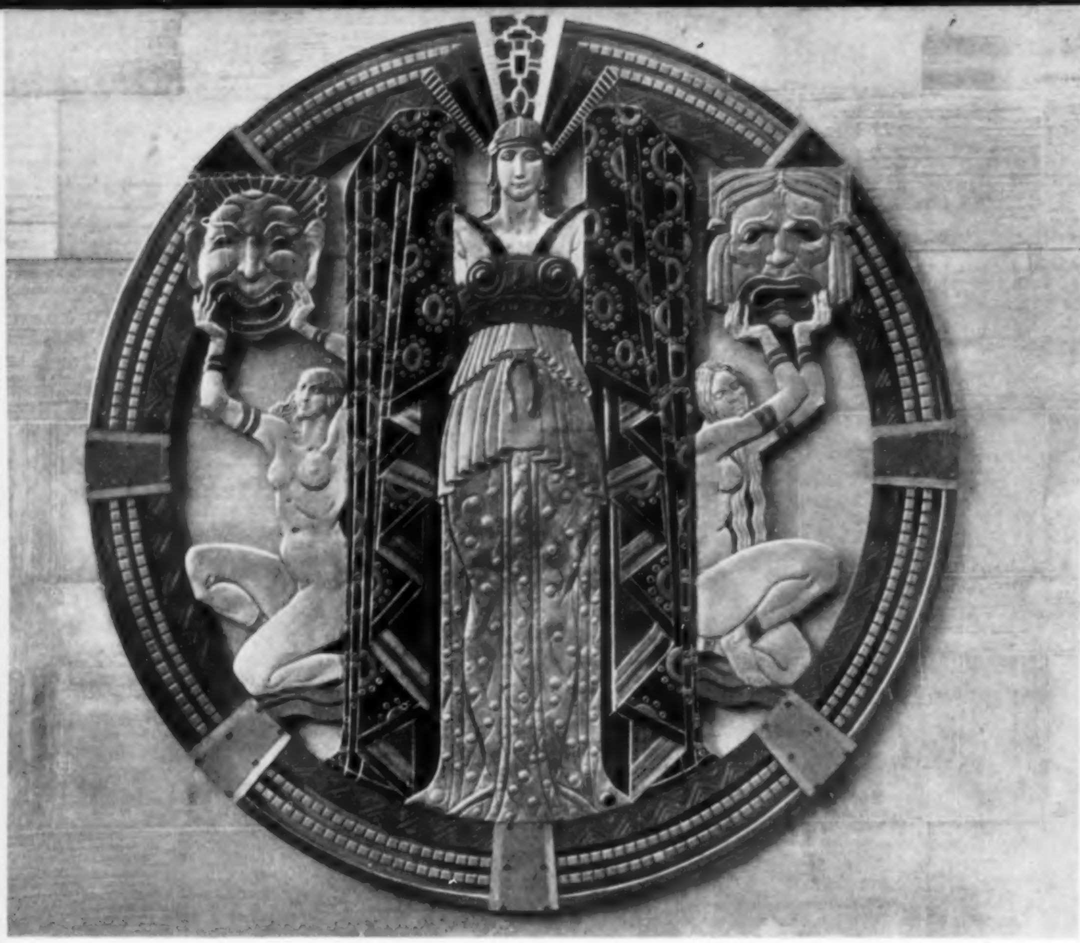
The speaker is Oscar B. Bach, artist and craftsman, whose outstandingly original work is found throughout the world in museums, in churches and temples, in public buildings and in private residences. To a heritage in arts, in crafts, in sciences extending down through generations in his own family, and to an intimate knowledge of the works and techniques of the old masters in Europe, Mr. Bach has added the ability to visualize the possibilities possessed by the most modern metals as a medium for the more effective expression of his artistic concepts.

Mr. Bach continued: "Early sculptors expressed themselves in three dimensions through the use of marble, granite and other materials such as the softer metals — all that were then available. The natural characteristics of these materials created limitations in their use. For decorative purposes, most large sculpturing, even when in low relief, necessitates a tremendous amount of bracing and support, as the material used can seldom carry any structural load. Now the stainless steels make it possible for artists to work in a material that is as strong and dependable as it is beautiful."

The interviewer here interrupted: "We metallurgists, Mr. Bach, sometimes wonder what we can do to bring these new materials more prominently to the attention of architects and designers. With a few outstanding exceptions, they seem to think that the new materials are troublesome to handle and perhaps not altogether as good as advertised!"

"You should counsel patience," was the answer. "There really *is* an extensive use for architectural decorations, both outside and inside important new structures. Stainless steel store fronts, vestibules, railings, bank cages and fixtures, vaults, grilles and furniture are increasingly used in the more modern buildings.

"I admit that it would perhaps have been wrong and premature to have attempted to introduce the broad use of stainless steel sooner,



Brilliantly Colored Repousse Plaque Symbolic of Drama. One of three on the exterior walls of Music Hall, Rockefeller Center, New York. Stainless steel was largely used in these ornaments, 18 ft. in diameter, combined with other metallic alloys, bare and enameled

because, during the last ten years many difficulties — like children's diseases — had to be cured by the mills, metallurgists, fabricators and craftsmen. Even more important, it has been necessary to inform and convince designers of its many virtues, since entirely new principles are involved and, as experience was gained, new avenues opened up for its use."

"What has been your experience in contacting prospective customers for your creations in wrought metal?"

"More than 20 years ago when I set out to design and practice my craftsmanship in this country, I scrutinized the usual methods and procedures employed here in this field of endeavor. It was then, and still is, customary for the architect to furnish designs and details for the metal work. A modeler would be engaged to interpret these designs in plastic material and provide models which could be duplicated in the material later to be selected for their construction.

"I have often been dismayed to observe how the designer's beautiful concept was defeated by the limitations placed on its realization by the materials and procedures employed by those to whom its execution was entrusted.

"After the modeler was through with his work, bidders were invited to give their estimates and the successful contractor would then be instructed to reproduce the models in white metal, bronze, brass, or other alloys — sometimes in plain cast iron with its inevitable painted surfaces. The final results would not be a matter of artistic craftsmanship but rather an exhibit of wit and cunning to evade the limitations of material and technique.

"Such models were needed to show those who were casting metal in molds how the surface should be profiled — no craftsmanship or nuances of expression were involved. Stainless steel releases the designer and the craftsman to enjoy the fullest attainment of his aim and purpose.

"With the opportunities offered to us with this beautiful prince of steels, we no longer have to conceal our basic materials and we can really proceed to design and write specifications, and the fabricator and craftsman can go ahead in actually executing work that will enhance any structure or edifice with its beauty and truthful purity, instead of marring it with compromises."

Strength an Important Characteristic

One has only to look at the massive doors illustrated at the first of this article, worked in broad sheets of stainless steel, to realize that the speaker has surmounted the problems involved in such a chain of personal factors from architect to designer to modeler to workman. Answering a query as to what features of the new material are of outstanding importance to the artist, Mr. Bach said:

"Corrosion resistance has usually been regarded as the outstanding characteristic. I do not want to detract from this feature, for it enables the artist to gain immortality for his work — it will be everlasting. We all have felt that rust is the great destroyer of the steel age, just as verdigris was the destroyer of the bronze age. It has menaced the purity of our chemicals from which come medicines and dyes and has stood as a bar to progress in all fields of applied

science. It has jeopardized our foods by the constant threat of contamination. It has eaten into the choicest productions of the craftsmen and ruined their pristine beauty.

"For centuries we have been looking for a steel that would not rust. Any other metal less strong than steel would not do. Only kings and emperors could afford to command an artist to work in gold, yet we yearned for a truly noble metal. Protective coverings, even the very modern electroplating, were far from satisfactory — they were so very temporary. The real solution and the real success to overcome this destroyer, rust, is found in stainless steel.

"Important though this matter of permanence is, both from the standpoint of inspiration and economics, I would like to impress the thought that the artist must keep in mind the new values and principles of this material.

"The most important feature is its great tensile strength and ductility. When working in thin sheets of stainless steel of the chromium-nickel varieties it is actually possible to increase its strength approximately four times by the simple process of hammering to develop the details of a design in relief. Where previously tremendous thicknesses — I mean tremendous by comparison with sheet metal — had to be considered, the designer learns to think in the terms of manifold and new fabricating processes made possible by the present knowledge of this material, always keeping in mind the much greater tensile strength and hardness in comparison with more ordinary metallic alloys.

"Flat strips, 16 gage or lighter, can be drawn through mechanical rolls and then formed into any desired shape and profile, as for instance in the fabrication of stainless steel windows and architectural trim. Stainless steel can be welded, wrought, forged, repousséd, spun, stamped, rolled, cold drawn. It lends itself especially to cold treatment since working it thus increases its tensile strength. However, for many forging operations it is necessary to work it hot in a manner similar to steel or iron. This, however, is readily done.

"Graceful grilles and doors no longer have to be cast in heavy materials, but can be light enough to be carried and erected by the average workman. They will, on the other hand, have a strength and endurance out of all proportion to so-called hollow bronze doors or even the massive cast bronze doors."

Mr. Bach was reminded that he used other metals and even enamels in the construction of the heroic plaques on Music Hall in Rockefeller Center, New York, and he said it was necessary at that time to do this to produce the necessary color contrast.

"About two years ago," he continued, "I was asked to suggest a method of coloring the natural finish of stainless steel, with the proviso that it must not be paint nor anything applied to the metal or added to the metal that would cause it to deteriorate nor involve the use of a process which would in any way corrode stainless steel.

"I experimented along these lines and eventually succeeded in adding an apparent improvement by coloring the surface of this metal. I confess, though, that I am a little ashamed, because it really seems like trying to paint the lily. The trim around the door illustrated on page 36 is made of such 'colored stainless,' imitated by the front cover.

"Many architectural and sculptural masterpieces from ancient to modern times indicate that enduring results can be achieved when the artist utilizes to the fullest extent the natural characteristics — even limitations — of the material of construction. This I am sure will be the case with this new and precious metal."

Oscar B. Bach

With an inherited artistic ability developed by study at the Royal Art Academy in Berlin, he perfected his craftsmanship in metals through five years of work and study in Italy, Spain and France. He came to America in 1913 and about ten years later began to receive recognition for the originality of his work. For the past ten years he has been much interested in stainless steel as a medium for decorative metal work.

From a weight-strength basis there is little to choose between stainless and duralumin. Duralumin is more economical in parts carrying relatively small loads; stainless is more economical in the larger structures with heavier loads

Stainless for Aircraft Design and Fabrication

To THE DESIGNER of modern structures, stainless steel offers many interesting possibilities. Up to the present time several important applications have been made, but in comparison with the undoubted future developments, these are but the pioneering efforts of a few organizations whose efforts have shown it to be economically sound. Possibly the first notable instance of this sort was the skeleton of the British airship R-101, which utilized heat treated 13% chromium steel for the main members. In this country the high speed railroad trains of the well-advertised Zephyr type have car bodies made of an alloy containing about 18% chromium and 8% nickel (the so-called 18-8). This same alloy has been extensively used on shipboard, especially for masts, deck houses and bulkheads on naval vessels of the destroyer type, and a sizable amount has been used in the superstructure of the Normandie.

On account of the high price of the latter alloy it must be used in a way that will develop the highest strength with the minimum of weight. Designers of all types of structures, either stationary or moving, will find much applicable information in the aircraft industry, which has established a standard of weight-strength efficiency higher than that existing in any other field. In the study of new designs, component parts, miscellaneous minor specimens and even small scale airplanes are subjected to exhaustive static tests before the aeronautical engineer is satisfied that he has done his utmost to reduce the structure to the lightest possible weight commensurate with cost and applied load. No "factor of ignorance" is added to the design load to compensate for secondary stresses or redistribution of load after the elastic stress has been exceeded. Admittedly, many of the allowable stresses used today are based on empirical data formulated from a multitude of similar tests, but since dead weight constitutes such an important part in the evaluation of the final airplane, all efforts are extended toward effecting the lightest possible structure.

It may be said at the outset that the only reason 18-8 can be used economically in competition with other materials is because of its superlative resistance to corrosion. Load-carrying members of structural steel are never used in really thin sections even when galvanized and built into transmission towers, because plain carbon steel rusts so quickly in all atmospheres, and failure would result from careless maintenance. When thin sections of heat treated alloy tubing are utilized, considerable care — and extra weight — is required for outside painting and protecting the interior surfaces of the tubes. Obviously a strong, rustless steel is necessary for sheets and stiffeners whose thickness is measured in thousandths of an inch. This limits the engineer at

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present to the stainless steels and the strong aluminum alloys. (Early troubles with the corrosion of aluminum have been avoided by the invention of "alclad" — a coating of pure aluminum — or by anodic treatment and painting of the surface. Even so the weight of paint on an aluminum structure runs into a surprising figure.

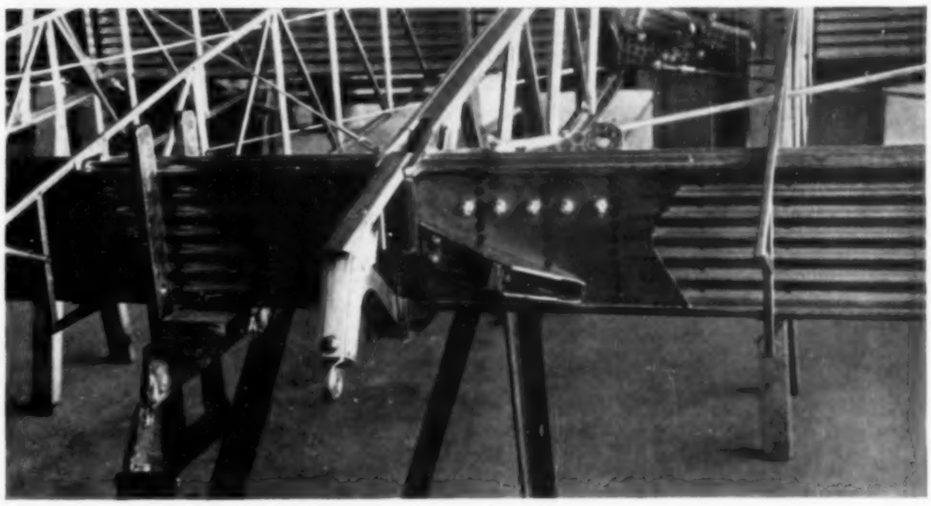
As pointed out by J. B. Johnson in METAL PROGRESS last October, nearly all modern aircraft except small sport and training planes is now constructed from a high strength aluminum alloy known as 24-ST, except that the landing gear and engine mounts, due to magnitude and concentration of the applied loads, are fabricated from heat treated chromium-molybdenum tubing. Aluminum alloy or welded steel tubing has supplanted wood for small aircraft skeletons because of permanence, durability, greater resistance to fire hazard, slightly greater strength-weight characteristics and adaptability to mass production. A small fabric-covered airplane could be built in approximately the same weight by using wood rather than the strongest aluminum alloy, but the psychological effect and relative greater safety of the metal skeleton would be a large factor in its favor. Bombers and transport planes are now of monocoque or stressed-skin construction and about 75% of the fuselage is of aluminum alloy.

This trend toward aluminum has been intensified by the development of a superior metal. The original strong alloy called duralumin by the Germans is covered in America by "17-S," "BH," Army specification 57-152A and Navy specification 44-A-2. It contains about 4% copper, 0.5% magnesium and 0.5% manganese. This excellent material has been still further improved by slightly increasing the copper and manganese and bringing the magnesium up to 1.5%. The resulting alloy in the wrought and heat treated condition is called "24-ST" by the Aluminum Co. of America, and "super-duralumin" in the aeronautic industry.

Since 24-ST aluminum alloy is used for the majority of airplane structures, it naturally follows that this material is highly efficient from a weight-strength viewpoint. Using this as a basis, the physical properties of 18-8 will be given in order to establish relative design values. This comparison is a very difficult one, since the greater thickness of the aluminum alloy for the same weight makes it a more rugged material and therefore less prone to elastic instability and buckling. A résumé of the physical properties of the two metals, however, will roughly indicate their relative merits.

Comparison of Mechanical Properties

Before any comparison can be made it is necessary that the two materials be reduced to an equivalent weight. The specific gravity of stainless steel is 7.92 while that of 24-ST is 2.79; the ratio between the two specific gravities is therefore 2.84. This factor will be used to modify the physical properties of the aluminum alloy so that they are directly comparable to those of 18-8 stainless steel. Furthermore the condition of the metal is important. Aluminum alloy sheet is furnished in the annealed and softened condition and must be quenched and aged to develop its strength; rolling, bending, shearing and punching may readily be done either before or just after quenching. Structural shapes, rolled or extruded, and thicker sheets are usually furnished in the quenched and aged condition. The stain-



Aileron Hinge and Wing Skeleton of Stainless Steel. Flying wire fitting is welded to main boom

less steel, 18-8, is an austenitic alloy whose strength is induced by cold work; it is bought almost exclusively in coils of thin strip, heavily cold rolled to "hard temper."

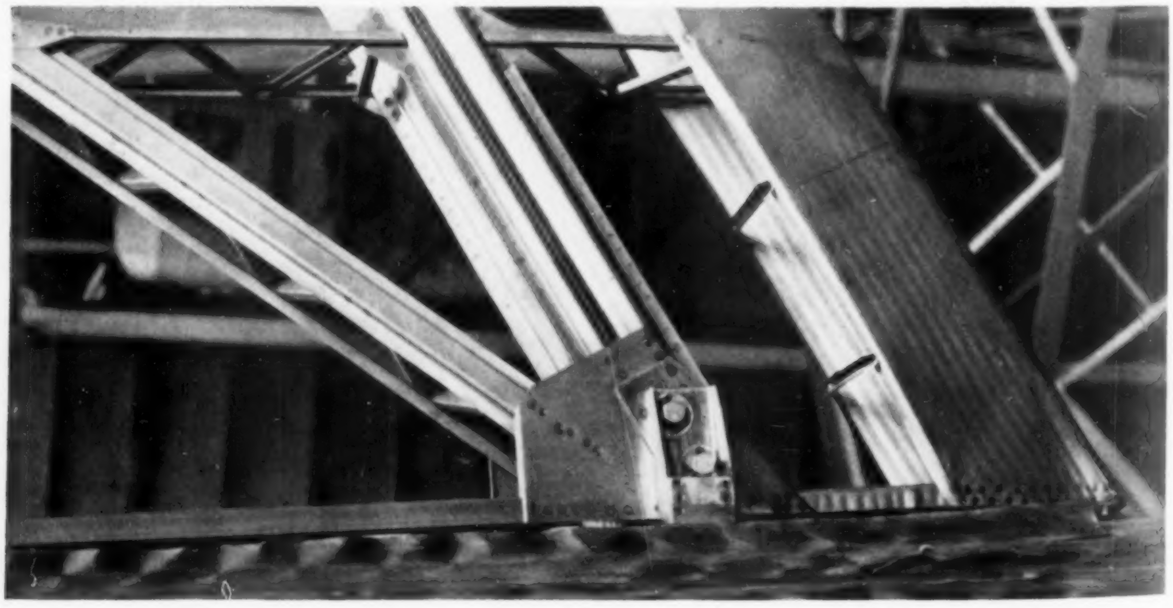
In tension, hard temper 18-8 has a minimum tensile strength of 185,000 psi.; 24-ST has an ultimate tensile strength of 64,000 psi., which multiplied by the factor of 2.84 gives a comparison figure of 182,000. There is therefore very little to choose between 18-8 and 24-ST as far as strength of tension members of equivalent weight is concerned, except that steel members subjected to direct tension can be approximately one-third smaller. This is of importance in exposed parts where drag or resistance to aerodynamic forces is important. Likewise terminals and end fittings are simplified if they can be made as small as possible.

A comparison between the two metals when used in compression members represents a very complex problem, since if there is no restriction on size the aluminum alloy can be disposed further away from the neutral axis and by so doing have a greater radius of gyration — that is, the member is stiffer against failure by buckling. We will assume, however, that an over-all diameter is restricted — this assumption being in accord with optimum aerodynamic efficiency. In a "short column" the efficiency depends almost entirely upon the yield point of the material. High tensile 18-8 has a yield point of 150,000 psi., whereas 24-ST has a yield point of 40,000 psi. Multiplying the latter by the factor 2.84, a comparable yield point of 114,000 is obtained. Therefore, for parts classifying as short columns, stainless steel is more efficient.

The load which will cause a long column to fail depends almost entirely upon the modulus of elasticity of the material. At a very low unit stress the modulus of stainless steel is 29,000,000 psi. Owing to the fact that the stress-strain curve deviates slightly from a straight line at moderate loads, the computed value of the modulus drops off as the unit stress is increased, but since the unit stress that a long column will support is of extremely low value due to elastic failure, 29,000,000 represents a close approximation of the actual condition. The modulus of 24-ST is 10,300,000 psi.; multiplying this by the ratio 2.84 results in a figure of 29,200,000.

Thus it can be seen that there is very little to choose between the two metals as far as compression is concerned; whereas the stainless steel is better in the short column range, the 24-ST is slightly more efficient in the long column range.

In bending a unit stress of 163,000 psi. has been realized in a built-up section of 18-8 stainless steel. In aluminum 52,000 psi. is the maximum bending strength obtainable from 24-ST; multiplying this value by the factor of 2.84 a comparative stress of 148,000 is obtained, which indicates that 18-8 stainless steel has a slight advantage over 24-ST when bending strength alone is considered. Where beams are limited in depth

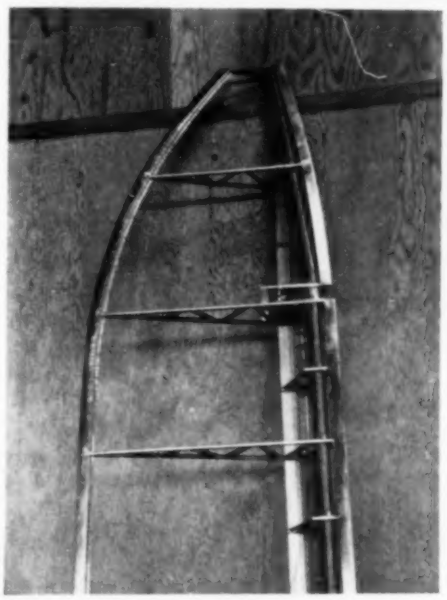


Joints and Stiffeners and Fittings in Heavily Stressed Members of Stainless Steel. Box beams and struts may confidently be installed without fearing corrosion

and must also be stiff against bending or flutter, stainless has the added advantage of a higher modulus.

18-8 stainless steel develops a fatigue limit of approximately 50% of its ultimate whereas 24-ST realizes only about 21% of its ultimate (J. B. Johnson gives 14,000 psi. for 24-ST). Since modern aircraft is designed on the basis of the ultimate tensile strength it is apparent that fatigue failures must be closely guarded against, and it is likely that stainless steel is better fortified against the effect of repeated stresses in places where they are not expected.

Method of Stiffening Stainless Steel Sheet, Paper Thin, With a Corrugated Piece. This is a flap designed for a Luscombe airplane



Aileron and Hinge of Stainless Steel, Shotwelded. This skeleton will finally be covered with fabric

As concerns impact, 18-8 stainless steel has a Charpy resistance of approximately 33 ft-lb., whereas 24-ST is approximately 10 ft-lb. Owing to the nature of this test, it is doubtful whether the latter figure should be multiplied by 2.84 for comparison.

The durability of both of these metals is high and obsolescence rather than disintegration or corrosion of the material is the ruling factor in the scrapping of aircraft at the present time. No predictions can be made in the future but it seems probable that as designs tend to approach the aerodynamic optimum the question of permanence of all materials will become of increasing importance. From a fire hazard standpoint 18-8 stainless steel is definitely better since its melting point is approximately twice that of aluminum. Of course, the cold worked 18-8 would be annealed and lose its high strength by passing through a fire, but structures will hang together at temperatures above the melting point of aluminum. Thus 18-8 tubes are giving almost unlimited service in oil cracking stills where outlet oil temperatures are about 900° F. and flame side metal temperatures undoubtedly reach 1200° F.

The above comparison between the two metals indicates that there is little, one way or the other, to guide the designer in making a selection of the proper metal for his structure. As pointed out before, the applied loads on the structure should be of such magnitude as to utilize a fairly heavy gage of stainless steel and by so doing minimize the local buckling and elastic failures. This premise points toward large airplanes as the best structures for stainless. They are heavily loaded and require a minimum of cross-section for maximum aerodynamic efficiency. In the small airplane as usually constructed, the selection of stainless steel would be dictated by the minimum gage obtainable from the rolling mill and the stability of the part made from these thin sheets rather than the stress requirements. As the size and loading increase, the thickness of metal reaches the figure where a better form factor and the utmost efficiency can be realized through the use of heavier sections and less closely spaced stiffeners.

Welding Versus Riveting

The one marked advantage that stainless steel has over the aluminum alloy is in its fabrication, since all joints can be made by shotwelding or very fast spot welding rather than riveting. This process of welding can readily be developed into an automatic set-up and it is possible to construct an entire airplane without using a single rivet. The unit cost of spot welding is materially less than riveting and has numerous advantages from an airplane designer's point of view.

For instance, the number of spot welds in a given joint is not important except from a cost

standpoint. The welds, of course, weigh nothing. Since they do not project from the surface they allow flush connections and when used on external surfaces are better from a standpoint of aerodynamic drag. The greater number of shotwelds used in a given fitting tends to reduce the stress concentration and results in a larger margin of safety. Since no material is removed (as in a rivet hole) the joint can be designed for 100% efficiency rather than for 75%. Finally a shotweld requires less space and flange width than a rivet and the proper design of a welded joint should result in a minor saving in weight.

Overlapping shotwelds form a seam weld and a watertight joint, which when used in seaplane construction results in an extremely efficient method of closing the seams. This type of seam is completely watertight and does not require any caulking material to be placed on the faying surfaces and around the rivets, thereby resulting in a lesser weight for the seam itself. If this same method were to be extended to the cabin of a stratosphere airplane, it would be possible to obtain an airtight joint which could be relied upon under very difficult conditions.

Riveting is a very expensive process, and admittedly unsatisfactory in joints where rapidly alternating stresses are carried or in seams where tightness is essential. A great amount of work has been done to find a method of welding strong aluminum alloys, but the electrical resistance of aluminum is so low that the spot welding methods so successful for 18-8 are inapplicable.

Welding Equipment

Adequate automatic equipment for steel has been developed. The duration of current can be controlled either by a cam-operated mechanism or by electron tubes. Simple indexing devices are available whereby the assembled work, mounted on a table like the bed of a planer, can be fed past the electrode grips at definite rates, thus putting in spot welds at correct spacings at a high rate of speed. For semi-automatic operations, four sets of welding horns or electrodes can be arranged at right angles in plan around a square mast containing a single transformer, with current control interlocked to avoid interference in the event that operators would depress their treadles simultaneously. Portable devices of pincer type are also successful.

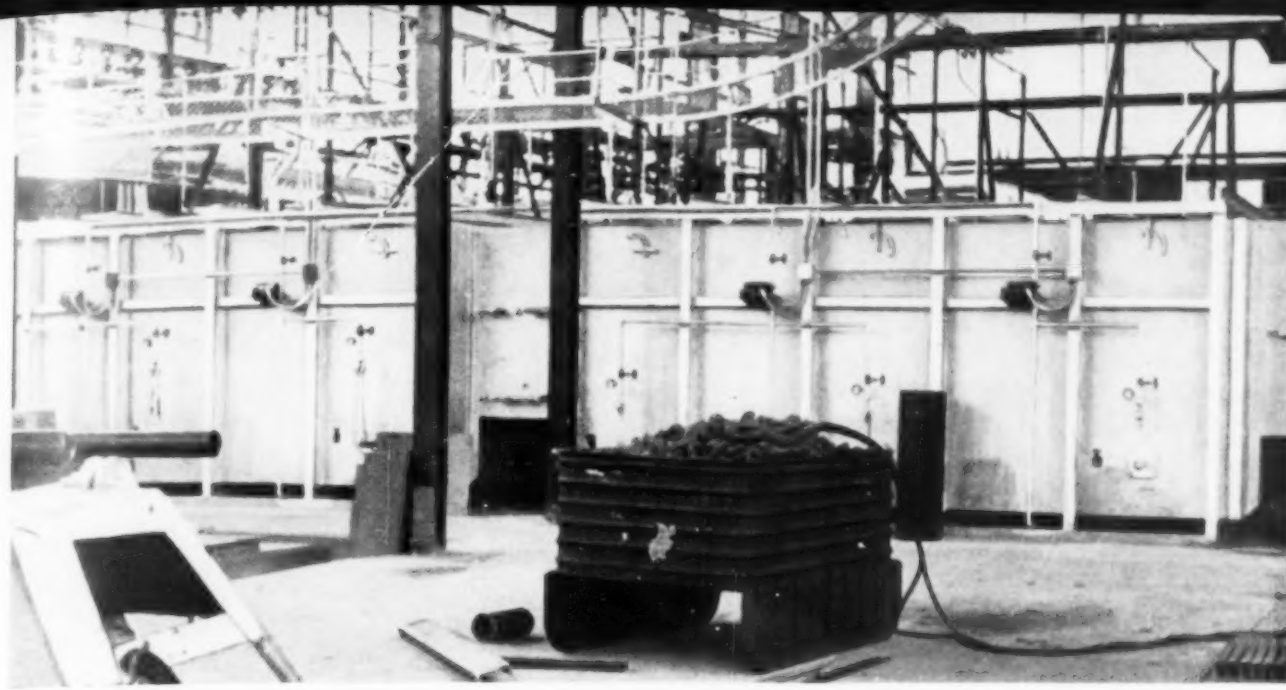
On the other side of this picture it must be admitted that dozens of shops and workmen are capable of making or replacing a rivet to one that is equipped for a spot welding job. This, however, is a temporary condition; the ratio will continually decline, and it will be found just as easy to install welding equipment as it is drilling and riveting devices.

Cold rolled stainless steel is readily sheared, bent or flanged. Dished shapes or fluted flanges (work which cannot be formed by rolling or drawing through dies) are easily bumped up or stamped in a drop hammer between cadmium alloy dies. These low-melting alloys may be cast against wooden or plaster of paris models. Trimming or cutting of bent shapes is best done by a thin abrasive wheel.

Cleanliness is a great advantage in the stock room. The cold rolled alloy is delivered with a superfine surface, ordinarily interleaved with paper to avoid rub. Such metal deserves careful handling. We have carpeted our stock room and run a vacuum sweeper over it every day.

In conclusion, it may be said that the correct decision as to the best metal for weight saving in moving structures is made on the basis of other factors than physical tests. It is roughly true that wood, heat treated steel, super-duralumin and cold rolled 18-8 are about equal as far as strength-weight factors are concerned. Actual use is determined by such factors as fire hazard, adaptability to mass production, availability in proper sizes, shapes and thicknesses, corrosion resistance, amount of load the part is to carry, and ease of fabrication and repair.

The use of stainless steel rather than 24-ST for efficient structures is therefore determined by the final assembly rather than by any inherent physical characteristics of the two metals. In production, indications are that shotwelded structures can be fabricated at a much lower cost than the ones which are completely riveted, and it may confidently be predicted that in large moving structures this saving in fabrication will more than counterbalance the extra cost of stainless steel strip as compared with super-duralumin sheet and shapes.



Continuous normalizing furnace for gear blanks, having water-jacketed cooling zones near mid-length and at discharge end — one of the interesting installations in the new Chevrolet gear plant

Equipment for Hardening Gears Without Oxidation

A NUMBER of interesting new ideas are incorporated in the equipment of the new forging and heat treating plant at Chevrolet Parts Mfg. Division of General Motors Corp. at Saginaw, Mich. Most of the production is gears of one sort or another. The forgings are normalized in a furnace having a central cooling zone. After cutting the teeth they are hardened from a controlled atmosphere having definitely carburizing tendencies. A unique installation for heating and quenching from lead baths is also installed, as well as a model battery of cyanide pots. Gas is the fuel standardized throughout this plant, and is used in all the furnaces, both for forging and for heat treating.

A side view of the normalizing furnace is shown in the view at the top of this article. Temperature cycle consists of heating to 1680° F., sudden cooling to 1330° F. and holding for a definite period. The furnace is about 33 ft. long, the work tunnel about 18 in. high above the rails, and wide enough to pass two lines of 30-in. trays. The height of this space is shortened to 14 in. at the 3-ft. central cooling zone by two baffle arches, and pipes in which cold water is circulated are located both above and below the work. A second cooling zone 5 ft. long is built at the discharge end. From here the trays run out on a chain conveyor, with chains set far enough to clear the tray except for lugs at one edge. This tips the trays so the forgings dump automatically into tote boxes, and the trays are returned to the other end of the furnace by chain conveyor.

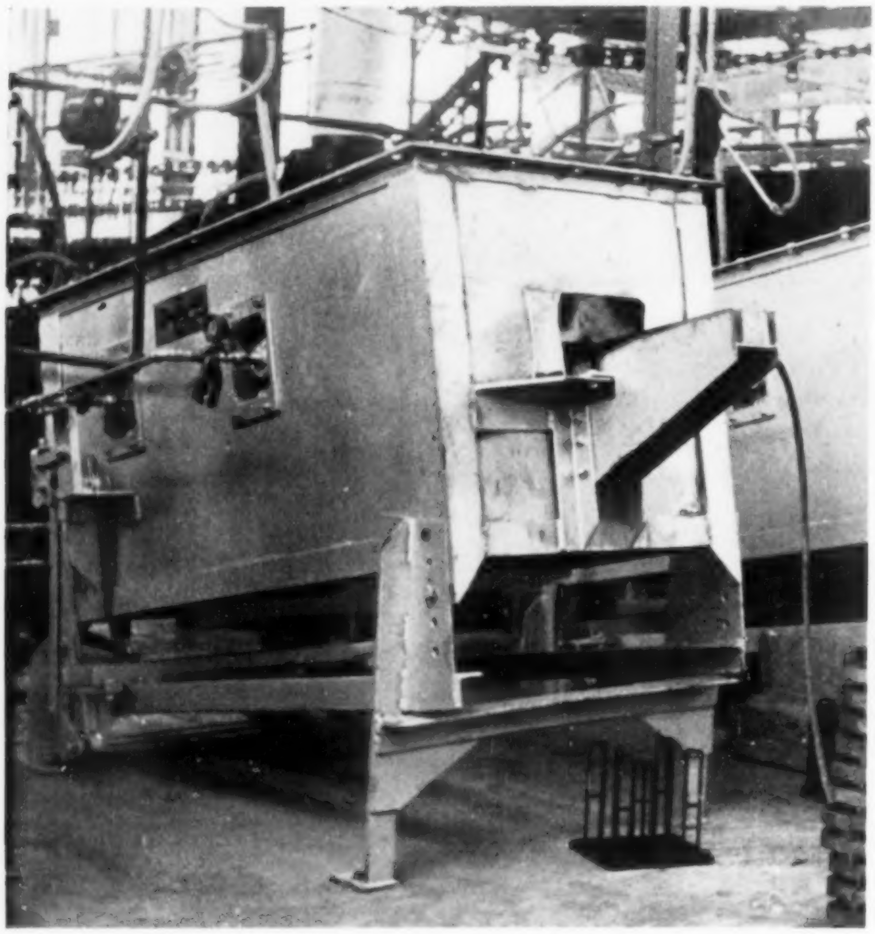
By J. B. Nealey
American Gas Asso.
New York

After the teeth are cut the gears are sent back for hardening. This is done in a variety of ways, first condition being the exclusion of oxygen or combustion gases which decarburize enough for a soft skin. There are two furnaces of pusher type with controlled atmosphere. Each is 32 ft. long, provided with an alloy muffle 32 in. wide, 16½ in. high at the ends and 2½ in. higher in the center. It is made up of sectional castings and longitudinal lugs are cast in the floor to form three continuous rails from one end of the furnace to the other. The muffle is closed at both ends by pairs of gate valves, thus forming air locks when work enters.

Prepared and dried gas, introduced into the muffle, constitutes the atmosphere, definitely carburizing in nature. Fuel gas is the basis of this atmosphere and it is prepared very simply and under close chemical control in a separate unit.

Gears take about 8 hr. to pass through this furnace, the temperature being maintained automatically at about 1700° F. This gives a case depth of from 0.040 to 0.050 in.

Some of the work going through these furnaces is cooled slightly in the air and then reheated for quenching in oil. There are two of these hardening furnaces, and, as shown in the accompanying view, they are interesting as being sloped at about 15° so that the circular parts will roll through alloy channels.



Hardening Furnaces With Inclined Troughs Down Which Preheated Gears Roll by Gravity, as They Are Withdrawn One by One at End

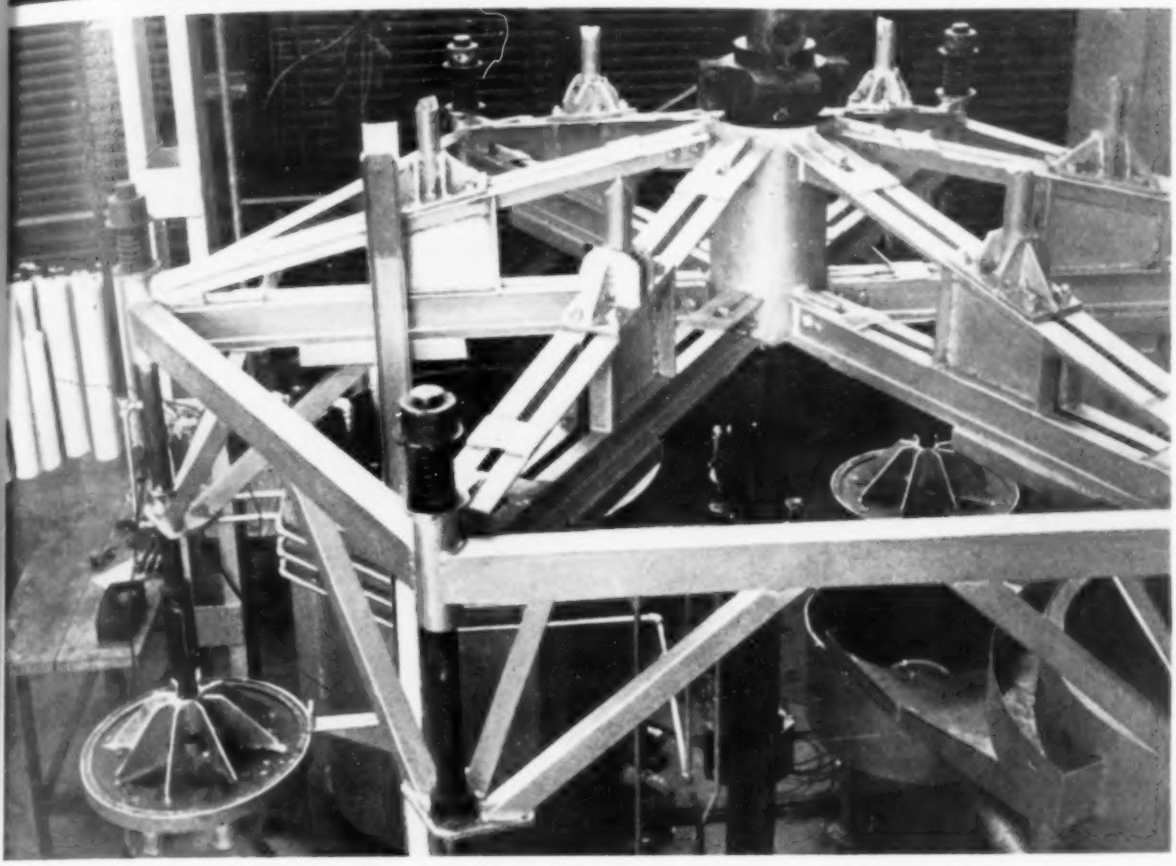
At the bottom end of each of these slots is a yoke-shaped fixture, actuated by a foot treadle — tripped once and a part rolls into the yoke; tripped a second time and it rolls out to where the operator can seize it with tongs and transfer it to a quenching press.

Automatic Transfer

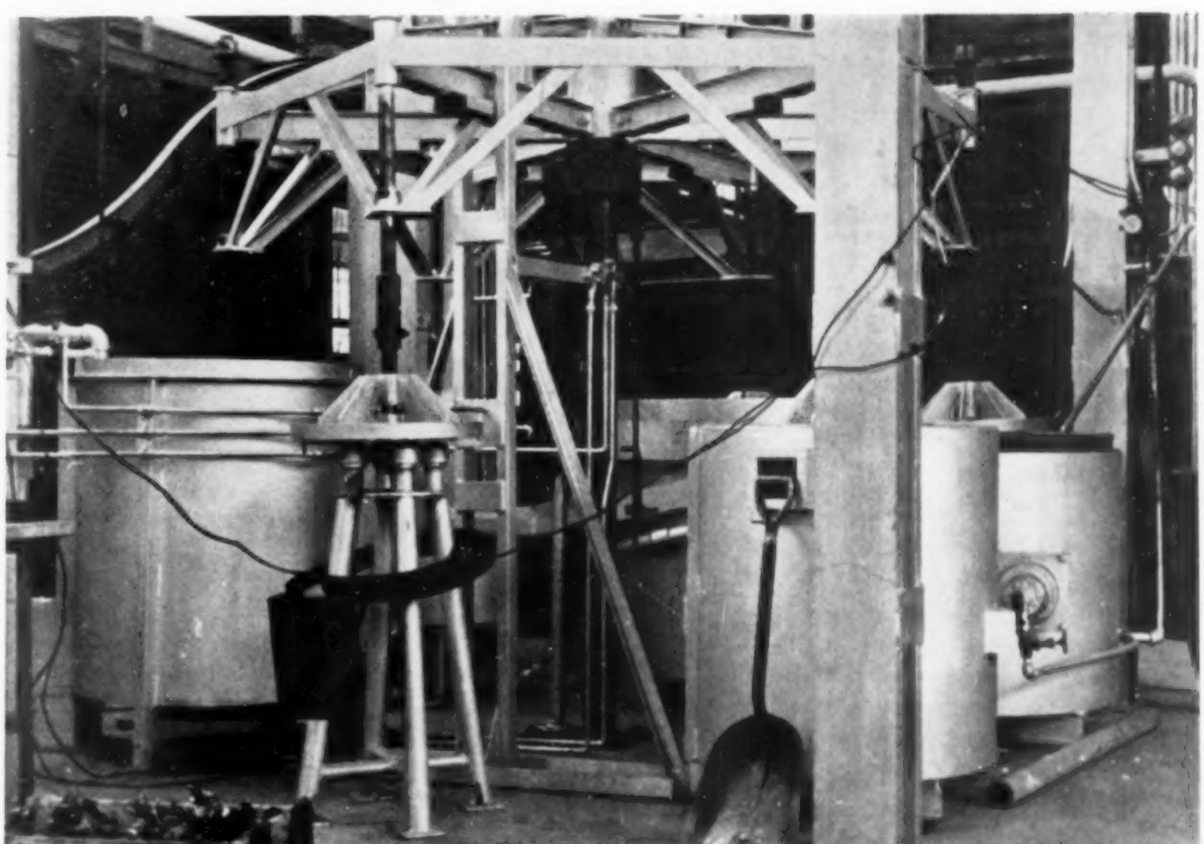
A unique set-up in this plant consists of a spider on top of a vertical plunger which places work progressively in a preheat furnace, a lead pot, a quench, and a wash tank. Fixtures carrying the work are suspended from the arms of the spider and each time the plunger operates the work is shifted from one unit to the next. The preheat furnace (oven type) is heated by waste products of combustion from the lead pot. This latter is fired with two gas burners. Both furnaces are circular, 4 ft. in diameter and 3 ft. high. The wash tank is heated with a ring type gas burner.

This new forge plant, with its 62-ft. ceiling, has ideal conditions as far as cleanliness and ventilation are concerned. This means that extensive cyaniding operations must be adequately hooded. How well this is done is indicated by the last photograph (page 48). Two parallel rows include 15 cyanide pots and three lead pots. The fumes discharge through hoods into a large duct just above the center aisle. Alongside the rows are quench tanks, 30 ft. long, sunk below floor level. Each furnace casing, 4 ft. in diameter and 3½ ft. high, is heated with two gas burners. The cyanide pots themselves are 2½ ft. in diameter and 2 ft. deep.

In the design of this new building at Chev-



Top and Side View of Equipment for Lead Hardening Grouped About Central Plunger. Overhead spider transfers loaded fixtures from one operation to another



rolet Parts Mfg. Division much attention has been given to the problem of materials handling as well as light and ventilation. The lower eight feet of the walls are steel roll-up doors extending from column to column, so that industrial trucks can enter at any point around the building. Overhead traveling cranes, set high enough to clear even the largest hammers, command the entire floor area. A covered conveyor operates between the new building and the older part of the plant, carrying forgings and gears, rough and machined, from forge shop to machine shop, back to heat treat, and at last on to final inspection and assembly.

Double Row of Cyanide and Lead Pots, Closely Hooded, and Set Between Long Quenching Tanks, Below Floor Level. View shows automatic temperature controls, tell-tale lights, and chain conveyors for transporting work

Properties of Some Special Bronzes

By D. Hanson and M. A. Wheeler

Condensed from Journal of the British Institute of Metals

IN STUDYING bronzes containing 3 to 10% tin and 1 to 7% aluminum, usual difficulties were had in obtaining ingots free from surface blemishes by the trapped oxide skin. The method finally adopted was to tilt the mold, and to pour the stream of metal down the narrow edge; in this way the defects were mainly confined to this edge, and their effects could be estimated.

Rolling properties were investigated by noting the degree of reduction before the characteristic shear cracks formed at the edges. All of the alloys were successfully rolled after annealing 12 hr. at 1350° F., reduced 50% cold, reheated 1 hr. to 1300° F., and cold rolled to a total of 80% of the original. Hot rolling after annealing 14 hr. at 1400° F. was easily done on all alloys which were converted to a solid solution alloy by this heat treatment.

Annealed alloys possess very good ductility; the maximum tensile strength attained was 67,000 psi. in one with 4% Al and 5% Sn.

The original surfaces of the "as cast" ingots containing more than 2% aluminum are comparatively resistant to scaling up to temperatures of 1500° F. If, however, the cast surface is machined, all the alloys form a dark colored oxide at 600 to 800° F.

(Continued on page 100)

The potential strength of heat treated stainless steel is usually neglected in favor of metal annealed for easy fabrication. Present uses where strength as well as corrosion resistance is necessary suggest many new applications

Corrosion Resisting Steels for High Strength

IN nearly all of the applications of stainless steel coming before the eyes of the ordinary citizen the stresses carried are nominal. In others well known to the specialist an enormously difficult metallurgical problem has been correctly solved. Corrosion resisting steels are naturally intended to resist specific types of corrosion. When such steels must also maintain heavy loads, sometimes for a long time at elevated temperature, the metallurgist has combined in one metal three properties, each one of which taken singly is hard to produce even in a specialized alloy!

However, it is unsafe to generalize too much. It must be remembered that the foregoing sentence is full of relative terms; what may be corrosion resistant to an oil refiner may not be satisfactory for a dye maker; what may be high strength for steam valves may not be nearly strong enough for an ammonia converter; what may be high temperature for turbine blades is cool for gas engine valves; a steel may be stainless in food stuffs at room temperature, but quickly tint to a bronze color in a baking oven. Intelligent care is needed in all new applications.

Steel, as is well known, is a malleable alloy of iron and iron carbide. The iron itself is not particularly strong — the iron carbide is its most powerful strengthening and hardening element. Neither is iron a very durable chemical element; iron rusts; it combines readily with oxygen, water, and various acids. Carbon is of no aid in this respect, but fortunately three other chemical elements can be alloyed with iron to decrease its rate of oxidation or scaling, namely, chromium, silicon, and aluminum. All of these metals are reasonably common (inexpensive, not rare), but high silicon-iron and aluminum-iron alloys are more difficult to make and fabricate. Therefore chromium is the commercial alloy par excellence for chemically stable steels, with silicon and aluminum added at times in smaller proportions primarily to intensify the anti-scaling effect.

It is generally believed that oxidation resistance is due to a reaction product that quickly forms, practically impervious to the reacting liquid or gas; likewise this film must be self-healing, else pitting will occur at chance irregularities. Chemical stability (in the above sense) is therefore a surface phenomenon. On the other hand, high static strength or creep resistance is not a surface but a deep-seated phenomenon; it is due principally to the presence of an infinite number of infinitesimal hard particles (usually carbides) dispersed throughout the whole mass. To complicate matters, the three alloying elements chromium, silicon and aluminum, when present in sufficient amount to give surface sta-

By Ernest E. Thum
Editor, Metal Progress

A summary of points brought forward in an address before the A. S. T. M

bility to the iron, also derange the normal relationships between the metal and its strengthening carbides. The result is that the alloys of iron which have highest chemical stability are so highly alloyed that they have the characteristics of *iron* rather than steel and cannot be strengthened by heat treatment, whereas the true, hardenable chromium steels are not as corrosion resistant as might be desired.

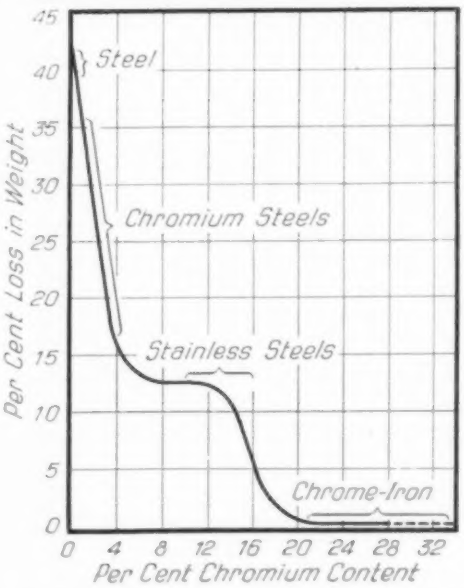
This situation is shown in two curves. The first shows the decreasing scale loss of iron alloys with increasing chromium. The second shows that a few per cent of chromium has considerable effect on the *annealed* properties of alloys containing 0.10% carbon; but that increasing chromium is thereafter relatively less valuable as a strength giver. Note the break in the curves at about 15% chromium. Below that figure the alloys are steels and hardenable. Above that figure they contain so much ferrite, or alpha-delta constituent, as to be relatively unaffected by heat treatment — they are irons.

Pages 56 and 57 of this issue may be consulted for data on the mechanical strength of several commercial alloys in the wrought form. Castings will not be discussed here, not because they are regarded as low-strength parts, but in the interest of brevity.

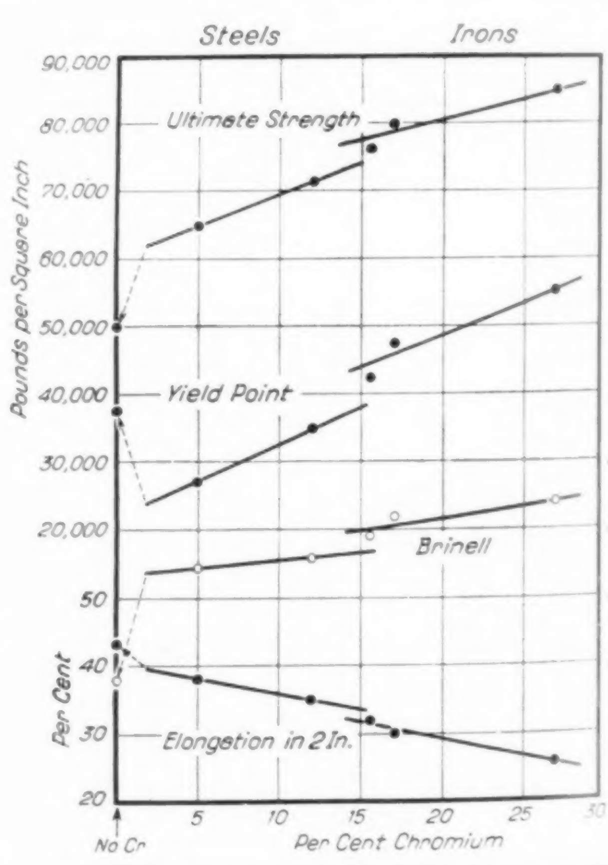
As will be seen in the sequel, chromium is a tremendous hardening element. But since the stainless *steels* are almost always utilized in the annealed condition, and the high chromium, low carbon irons are non-hardenable by heat treatment, the conclusion is obvious that the inherent possibilities of the alloys are neglected. A notable exception is the case of 18% chromium, 8% nickel steel, which may be and is hardened and strengthened greatly by cold rolling and wire drawing.

While alloys containing less than 13% chromium should not properly be classed as "stainless," the chemical stability lent by even a little chromium has warranted the production of a whole series of lower chromium steels, used largely in the petroleum industry for still tubes, and more recently by central steam power plants. Depending upon the corrodibility of the liquid phase, the temperature and pressure of the operation, and the expected life of the equipment or process before it is scrapped for a more efficient one, the designer selects carbon steel boiler tube, 2½% chromium steel, 5% chromium, 9% chromium, 13% chromium, or even higher complex alloys for his material of construction.

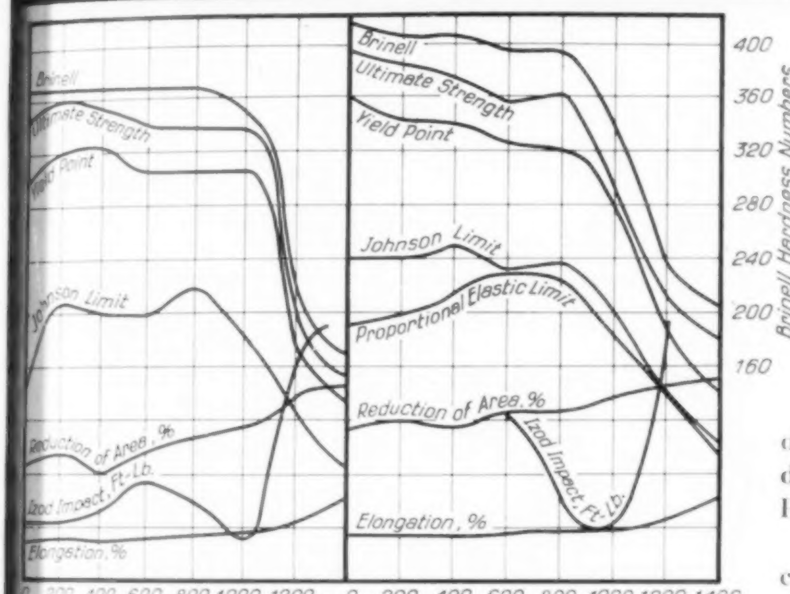
As little as 2% chromium pronouncedly reduces corrosion by crude petroleum at high temperature and pressure, but the 5% chromium steel is



At Left Is Curve (After C.E. MacQuigg) Showing Loss in Weight of ½-In. Cubes After 48 Hr. in Air at 1835°F. Iron alloyed with 26 to 28% chromium maintains a tinted surface indefinitely without further scaling up to 2100°F. . . . Below is plot showing that high chromium does not increase strength of 0.10% carbon-iron alloys much in the annealed condition. Available figures for reduction of area are erratic and not plotted



used in greatest tonnage. It is furnished, fabricated, and used in the soft annealed state, and can hardly be classed as a high strength material — at least as far as room temperature tests and services are concerned — although it performs very well under heat and pressure. It air hardens to an important degree, and this causes difficulties in fabricating — especially welding, which must be done on preheated parts and the joint immediately annealed. Some slow changes have been known to occur after long time at high temperature, which reduce the toughness of the cold metal, even though the hot metal is still quite reliable. Fortunately a fractional per cent of molybdenum in the alloy will prevent



Heat Treatment Will Develop Excellent Properties in the Stainless Steels. Diagram, after N. L. Mochel, shows effect of drawing after quenching from 1750°F. Steel at left had 11.75% Cr. at right 12.25% Cr; both had 0.09% carbon

this embrittlement. Molybdenum also mitigates the bad effects of tempering at 800 to 900° F., and improves the high temperature creep resistance. On the other side of the picture, it increases scaling quite materially.

The difficulties with welding the air hardening 5% chromium, and chromium-molybdenum steels have been avoided by adding enough titanium to prevent air hardening. Six to eight times as much titanium as carbon is necessary. Metallurgically, the effect is as though the titanium locks up the carbon in a compound which takes no place in the ordinary reactions, but is dispersed throughout the microstructure, as inert as a non-metallic inclusion.

Since chromium steels have been used for 70 years for their extreme hardness and strength, it is surprising that this property has not received more attention. Of course the S.A.E. steels use up to 1.50%, and the maximum mechanical properties in the heat treated condition can probably be achieved in a 3% chromium, 0.30% carbon steel. Mere air cooling of a 5% chromium, 0.10% carbon steel will induce an ultimate strength of 180,000 psi.

This inherent strength of the higher chromium steels is merely potential, as far as equipment for high temperature, high pressure service is concerned. The air hardening characteristics are a positive detriment to welding, and for bending, tube expanding, and other fabrication operations a soft, ductile alloy is required. Likewise the properties that could be induced by a quench and draw are useless at a higher temperature than the draw. The user therefore evaluates the material on the basis of first cost, easy fabrication, corrosion and scaling resistance, creep strength, and retained toughness — all in relation to the expected life of the equipment in question. (Fabrication properties of all the stainless steels are summarized in a data sheet published in February's Metal Progress, page 49.)

Two instances may be cited where the chromium steels are used in the heat treated state. The first is in steam turbine blades, where a combination of corrosion resistance, hardness, strength, and endurance against repeated stress is demanded.

Graphs on this page show the effect of various drawing temperatures after quenching such steels from 1750° F. The one at the left had 11.75% Cr, the one at the right 12.25% Cr. Both had 0.09% carbon. These are so near the limit where the alloy no longer responds to heat treatment (or at least rather erratically) that narrow chemical limits must be held, and medium tempering ranges are avoided. They respond to heat treatments exactly as does a plain carbon tool steel, except that temperatures and time required are modified in conformity with the natural sluggishness of high chromium alloys.

In turbine blades the ultimate is about 100,000 psi., and the toughness is exceedingly high. They are subjected to hundreds of mil-

lions of stress applications in their useful life, and their fatigue resistance is quite satisfactory (55,000 to 60,000 psi.) when tested either at room temperature or at 700° F., in dry air, dry steam, or humid air. If a jet of steam is played on the cool specimens in open air, allowing plenty of opportunity for liquid water to form in the presence of ample oxygen from the atmosphere, the corrosion fatigue limit ($N = 5\times10^7$) is cut about 45%.

Even though most excellent properties are available by heat treating, the desire to reduce costs has recently led to reduction of carbon to about 0.05% or the addition of about 0.50% aluminum to reduce the hardenability — the alloy thus approximates the properties of iron. Aluminum has the same softening effect as titanium in the 5% chromium steels already described (although the microstructural changes may be different).

Low carbon steels of the same general class are marketed in considerable quantity with chromium going as high as 15% where corrosion resistance is required. They may be used in the form of heat treated bars, or in strip, cold rolled to induce high strength. Most uses require fairly good physical properties and ease in fabrication; corrosion requirements are not the most exacting. Examples are coal screens, pump rods, valve stems and seats, equipment subjected to waters in coal mines, and cutting material and jordan bars for making fine papers (which must be free from iron and copper staining). A large quantity was made into bolts and suspension rods or hangers for the intake gates at Boulder Dam. An important outlet is in bank vaults and interior trim —chromium is then on the high side of the 12 to 15% range in order to increase the stain resistance.

More advantage should be taken by engineers of the wholly unusual mechanical properties of the original stainless cutlery steel, invented by Harry Brearley. As made in the United States, it contains 13.5% chromium (slightly more than the turbine-blade type), and 0.35% carbon max. The curves opposite average the results obtained from three tests on each of ten different heats of this material. It possesses the same combination of mechanical properties as the chromium-nickel and chromium-vanadium steels widely used for high strength parts in automobile and other high speed machinery, and in addition stainlessness against the weather, food stuffs, lye, ammonia, and animal products, and resistance against scaling up to 1700° F.

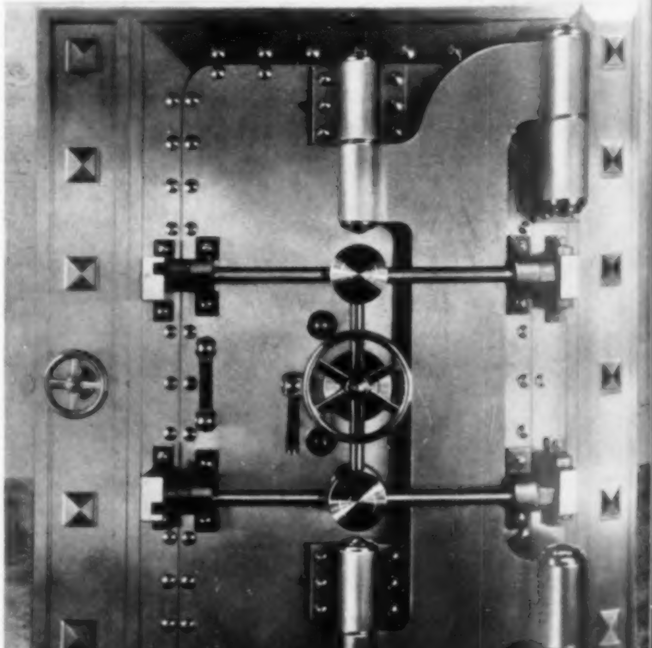
This original stainless steel, therefore, warrants more consideration. Its important engineering uses so far have been limited to exhaust valves for aircraft engines (now superseded by more complex steels), water pump shafts, and helical springs. It is not a simple material to handle or fabricate, but offers wonderful properties to those who are not looking primarily for low cost production.

It is worthy of note that the only rigid airship with a metallic skeleton other than duralumin, was the British R-101, whose girders and highly stressed parts were made of a straight chromium steel intermediate between the cutlery and the turbine-blade types and containing 12.5 to 14% chromium, 0.16 to 0.22% carbon. A temptation to discuss this application at length must be resisted since it has been done in Metal Progress for November, 1930.

However, it will serve to introduce a much more successful use of another stainless steel of entirely different nature, namely the 18% chromium, 8% nickel steels, ordinarily called 18-8, in the manufacture of light-weight moving structures.

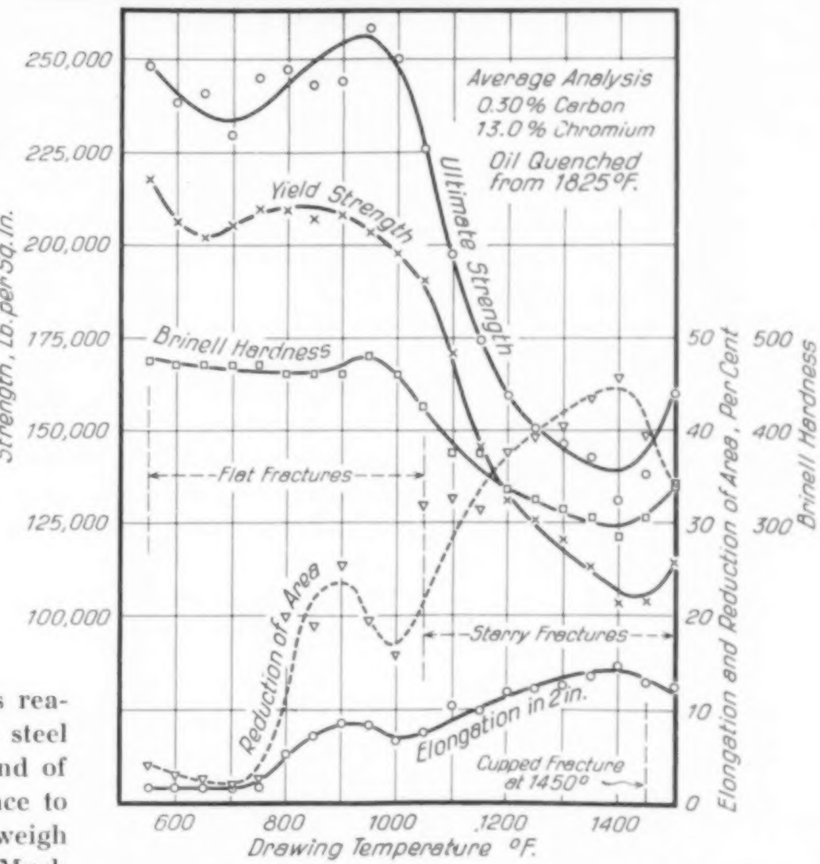
It is not necessary to discuss the metallurgical nature of this alloy. When quenched from a high temperature anneal it is a single-phase, non-magnetic alloy, a solid solution of iron, carbon, nickel and chromium. As shown by the table of properties on page 57 it is not very

Atmospheric Condensation ("Sweat") and Human Contact Cause no Marking or Change in Coloration in Low Carbon Stainless Steels Used in Safe Deposit Boxes and Vault Doors



hard or strong in the natural state.

Although the austenitic 18-8 is not hardenable by heat treatment, it does respond beautifully to cold work. It is easy to get ultimate strengths of 150,000 psi. in cold rolled strip — even 175,000 psi. Wire of 200,000 psi. and over is being produced regularly. The true proportional limit of cold worked 18-8 is low, yet it is a high strength material which can be flanged, bent, and otherwise cold worked during fabrication, and also is very stable so that it can be used in thin sections without allowance for atmospheric corrosion. It is well known that the material is so used for passenger car bodies for high speed railroad trains deck structures and masts on ships, and for strength members on airplane tails, wings and control surfaces.



The Original Stainless Cutlery Steel, Invented by Brearley, Has Strength, Hardness and Ductility Warranting Many Engineering Applications. Each point is average of 30 tests on 10 heats. (After O. K. Parmiter)

Railroad applications have been so far confined to passenger cars, for various reasons, one among which is the fact that the steel passenger car weighs 13 lb. for every pound of passenger so there is a much greater chance to save weight than in freight cars which weigh about 0.3 lb. for every pound of pay load. Much must be done in the high speed trains beyond lightening the structure, for only one-third of the weight is in the body, whereas one-third is in the appointments and one-third in the trucks. Nevertheless, it would appear that every pound saved in the body and appointments will save about $1\frac{1}{2}$ lb. in trucks and power plant.

These trains have proven all that can be asked for in reliability; operating costs are known to be enough lower than steam trains to retire the investment in two years. Running schedules are fast, and the public is patronizing them. The Burlington railroad, which pioneered this development with four articulated trains (now totaling in mileage over 1,000,000) has recently ordered two 10-car trains for a 16-hr. schedule between Chicago and Denver, making seven stops in 1040 miles. Compare this with 26 hr., the fastest steam train now on this run!

In designing these passenger cars the engineers attempt to make a more efficient use of a more efficient metal. No reduction in factors of safety is permissible. Since the roof and floor are indispensable and continuous members, they are utilized as the top and bottom chord of a large box beam, and trussing along the sides is constructed to take the shear stresses.

Joining difficulties have been solved by so-called shotwelding, which welds a series of small spots or overlapping spots (seam) between faying surfaces, using only enough time and heat to form the weld. This reheats or softens only the tiniest volume of adjacent metal.

When intended for car building, 18-8 is supplied in coils of strip, cold rolled to a minimum tensile strength of 150,000 psi. The strip is then put through a series of rolls to form various elements of the structural sections. Such sections are then fastened together into sub-assemblies designed to permit extensive use of automatic welding. Metal in such fabricated beams should be placed as far from the center of gravity of the section as possible, yet web members must be corrugated to prevent buckling in shear, and compression flanges also properly stiffened. All flat areas in compression must be supported or stiffened by beads, corrugations, or by auxiliary members.

Problems connected with light weight construction are, of course, intensified in aircraft, a

matter discussed at some length by W. L. Sutton on page 40 of this issue. Material for aircraft construction is furnished in sheets down to 0.005 in. thick, cold rolled to ultimate tensile strength of either 150,000 or 185,000 psi., and elongation of 25 or 15% respectively. Seamless tubing of round or streamlined cross-section, cold drawn to very thin wall and 175,000 psi. ultimate strength, is also available. Bar stock of 125,000 psi. is usually specified, although tension members have their lengths between clevis or screwed ends cold rolled to 200,000 psi. ultimate.

While most of the all-metal aircraft are now of aluminum construction, and stainless steel is therefore encountering an entrenched position, it is competitive in many locations both in strength-weight ratio and ultimate cost. Much more use has been made in England than here; there they favor a steel containing 18% chromium and 2% nickel. Seaplane floats and bodies are especially good applications. Exposed tierods, control cables, and tow ropes are standardized in 18-8 on U. S. army and navy aircraft.

For work aboard ships the weight savings are largely associated with the large margins in scantlings of ordinary carbon structural steel and plate necessary to insure safety even after severe corrosion. 18-8 is considered more or less immune to abuse by heating and can be welded or silver soldered with freedom in emergency repairs. Weight saving on the top sides is especially valuable in increasing the stability of the ship in heavy weather. There are many important naval applications of the corrosion resisting steels (including the chromium-iron alloys) in forgings and fabricated forms other than thin sheet, including fittings on water-tight doors, davit fittings, and non-magnetic parts in vicinity of the magnetic compass, as well as periscope tubes, clearing lines, and submerged control gear

The "Mark Twain," a Zephyr Type Train for the Burlington System, Leaving the Budd Shops for the West. Photo by Fred G. Ulberg

on submarines. Pitting type of corrosion, to which 18-8 is susceptible in stagnant sea water or in salt solutions deficient in oxygen, prevents its present application where it would constantly be in direct contact with sea or harbor water.

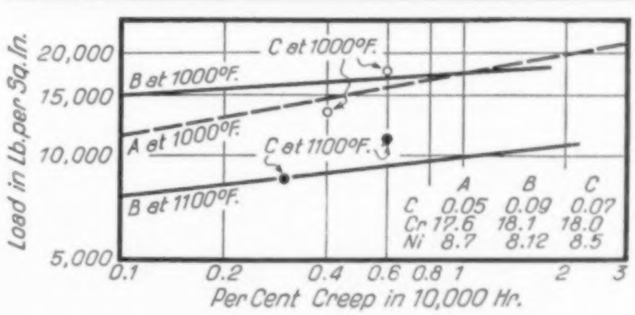
Another source of serious trouble in the early history of the alloy — one of the "growing pains," so to speak — is associated with the fact that its austenitic structure is metastable, that is, it slowly precipitates carbides from solid solution if held at temperatures between about 800 and 1600° F. Theoretically the tendency to precipitate exists below 800° F., but atomic mobility is so slight that formation and precipitation is practically frozen. Above 1600° F., the upper limit, this low carbon alloy re-enters the region where austenite is the true stable phase and any precipitated carbides are taken back into solution. (These temperatures vary with the carbon, the range widening at both ends as carbon increases.) Practically the method of insuring a fully austenitic microstructure is to reheat a considerable time at 1800 to 2100° F., (depending on carbon content) long enough to redissolve carbides precipitated in its former stays at lower temperature, and cool as quickly as possible.

The above action (namely, precipitation of an excess constituent from solid solution) is the essence of hardening. It is exactly in line with the so-called precipitation hardening utilized for the strong aluminum alloys. But unfortunately in 18-8 the excess constituent does not precipitate as a cloud of particles throughout the metal, as is necessary for useful hardening, but the sluggish action is largely confined to grain boundaries and to slip planes in cold worked material. Furthermore, the carbides are high in chromium, and rob the solid solution immediately surrounding them of so much chromium that what is left behind is insufficient to protect the iron from corrosion. Hence a corrosive solution or active gas eats into the impoverished films between grains, and the metal becomes embrittled even if, in time, not totally disintegrated.

Unless such a condition can be corrected, the 18-8 would be seriously limited in high temperature and corrosion resisting service. Likewise all welding operations would precipitate grain boundary carbides in some portion of the metal. Fortunately several correctives have been found.

We cannot take time to discuss these correctives, six in number. It must suffice to say that the one most used acts in the same way that the air-hardening, 5% chromium steel is converted to a soft "iron" — namely, adding enough titanium or columbium to lock up the carbon in harmless particles, and processing the metal so that the chromium-nickel-iron solid solution is substantially homogeneous and corrosion repellant. Such metal has been called a "stabilized" alloy. Any metal added in welding should evidently be supplied from rod or electrode containing ample titanium or columbium to produce a resistant alloy at the joint.

That this tendency to change its microstructure has not militated against its utility is proven by service records of high temperature equipment in the chemical and petroleum industry. The creep resistance (or resistance to slow deformation under high stress and temperature) is so high that tubing is made of it for super-power plants, and warrants the statement that this material is the best so far developed to meet *severe* conditions up to 1300° F.



Creep Resistance of 18-8 Steel C as determined by F. H. Norton After 31,000 Hr. in an Oil Still at 600 Lb. and 950°F., Is Very Close to That of Similar Steels A and B Tested Fresh From the Steel Mill

Installations in petroleum cracking units handling corrosive western crudes have operated over 25,000 stream hours without appreciable corrosion or erosion in the hottest locations where carbon steels require replacement every 60 days. In fact, the material long outlives the useful life of the rest of the equipment and has caused the oil man to turn to less expensive, lower chromium steels.

One might assume that the changes occurring in the microstructure in the 800 to 1600° temperature range would seriously impair its utility, but extensive tests on 18-8 withdrawn from long service in oil refineries show no decrease in creep resistance or increase in micro-grain size. Toughness remains high — Charpy impact 45 ft-lb. or higher. Conditions existing in a petroleum still, either inside the tube *(Continued on page 104)*

Properties of the Principal Cr-Fe Alloys

	2% Cr	5% Cr	9% Cr	12% Cr	Cutlery	17% Cr	27% Cr
Chemical composition							
Chromium	1.75 to 2.25	4 to 6	8 to 10	12 to 14	13 to 14	16 to 18	25 to 30
Nickel	(0.5 Mo)	—	(1.5 Mo)	—	—	—	—
Si and Mn (max.)	0.50	0.50	0.50	0.50	0.55	0.50	0.50
Carbon	0.15 max.	0.10 to 0.20	0.15 max.	0.10 max.	0.30 to 0.40	0.10±	0.10±
Specific gravity							
Lb. per cu. in.	—	0.280	0.282	0.276	0.278	0.273	0.270
(Mild steel = 1.00)	—	0.99	1.00	0.97	0.98	0.96	0.95
Electrical resistance							
Microhms per cm^3	—	—	—	57	60	59	67
(Mild steel = 1.00)	—	—	—	5.2	5.5	5.4	6.1
Melting range, °F.							
Top	—	2800	—	2790	2750	2750	2750
Bottom	—	2760	—	2750	2580	2710	2710
Structure	Pearlitic	Pearlitic	Martensitic	Martensitic	Martensitic	Ferritic	Ferritic
Magnetism							
Ferromagnetic	Yes	Yes	—	Yes	Yes	Yes	Yes
Permeability: As annealed	—	—	—	—	—	—	—
Permeability: Cold worked 10%	—	—	—	—	—	—	—
Specific heat							
C.g.s. units, 0 to 100°C.	—	0.11	—	0.11	0.117	0.11	0.11
(Mild steel = 1.00)	—	1.0	—	1.0	1.1	1.0	1.0
Thermal conductivity							
* C.g.s. units at 100°C.	—	0.0874	—	0.0595	0.05	0.0583	0.0500
(Mild steel = 1.00)	—	0.73	—	0.50	0.42	0.49	0.42
C.g.s. units at 500°C.	—	0.0803	—	0.0686	—	0.0624	0.0583
Thermal expansion per °F. x 1,000,000							
From 32 to 212°F.	—	6.1	6.29	6.1	5.7	6.0	5.9
(Mild steel = 1.00)	—	0.93	0.95	0.93	0.87	0.91	0.90
From 32 to 932°F.	—	7.2	7.00	6.7	6.6	6.7	6.3

Mechanical Properties at Room Temperature	2% Cr Annealed	5% Cr Annealed	5% Cr † Heat Treated	9% Cr Annealed	12% Cr Annealed	12% Cr † Heat Treated	Cutlery Annealed	Cutlery †† Heat Treated	17% Cr Annealed	17% Cr Cold Worked (Wire)	27% Cr Annealed	27% Cr Cold Worked (Wire)
Ultimate strength, 1000 psi.	60 to 70	66	115	75 to 87	65	125	100	230 to 260	75	100 to 190	75 to 95	85 to 175
Yield point, 1000 psi.	30 to 45	27	103	35 to 45	35	100	65	200 to 220	40	—	50 to 60	55 to 155
Elastic modulus, 10^6 psi.	—	—	—	—	28	—	—	—	29	—	—	—
Elongation, % in 2 in.	40 to 30	38	20	40 to 30	35	20	27	8 to 2	27	—	30 to 20	—
in 10 in.	—	—	—	—	—	—	—	—	—	25 to 2	—	25 to 2
Reduction of area, %	—	76	66	—	65	60	59	20 to 2	55	40 to 20	60 to 50	55 to 25
Impact, ft-lb., Charpy	35 to 65	—	—	35 to 60	—	75	—	—	—	—	—	—
Izod	—	~80	75	—	80	—	—	—	8 to 25	—	—	—
Fatigue endurance limit, 1000 psi.	—	—	—	—	—	—	—	—	—	—	—	—
Hardness, Brinell	130 to 160	136	250	145 to 180	140	230	170	480	175	185 to 270	160 to 190	150 to 250
Rockwell	—	B-75	C-24	—	B-76	C-22	—	C-56	B-85	B-90 to 105	B-80 to 90	C-0 to 25
Erichsen value, mm.	—	—	—	—	—	—	—	—	7 to 9	—	—	—
Stress in psi. causing 1% "creep" in 10,000 hr. at 1000°F.	11,400	7,000		11,600	13,000				8,500		—	
1100	5,650	—		6,950	—				—		—	
1200	3,150	—		2,300	2,300				2,100		1,600	
1350	—	—		—	1,400				1,200		400	
Scaling temp., °F.		1200		1200	1300		1750		1550		2100	
Initial forging temp., °F.		2100		—	2100		2000		2000		2200	
Finishing temp., °F.		About 1400		—	max. 1450		1700		max. 1400		max. 1400 to 1450	
Annealing treatment		Furnace cool from 1580°F.		—	Prolonged heating at 1250 to 1350°F.		1575 to 1625°F.		**		1 hr. or more at 1450°F. and quench	

* Thermal conductivity is measured as calories per sq.cm. per sec. per °C. per cm.
† Quenched and drawn at 1100°F. †† Oil Quenched from 1850°F. and drawn.
** Small cold reduction, followed by anneal at 1400°F. and quench

Properties of the Principal Cr-Ni-Fe Alloys

	18-8		18-12	25-12	25-20	18-26
Chemical composition						
Chromium	17 to 19	Modifi-	17 to 19	22 to 28	24 to 26	17.5 to 19.5
Nickel	8 to 10	cation	11 to 12.5	12 to 16	19 to 21	25 to 26
Si and Mn (max.)	0.50	with	0.50	—	1.0 & 0.75	3.0 Si max.
Carbon	0.10	titanium	0.10	0.15±	0.15 max.	0.20 max.
Specific gravity						
Lb. per cu. in.	0.286	0.285	0.287	0.283	0.285	0.280
(Mild steel = 1.00)	1.01	1.01	1.02	1.0	1.01	0.99
Electrical resistance						
Microhms per cm^3	70 *	71	73	78	90±	102
(Mild steel = 1.00)	6.4	6.5	6.7	7.1	—	9.3
Melting range, °F.						
Top	2590	2590	—	2570	2600	—
Bottom	2550	2550	—	2530	2550	—
Structure	Austenitic	Austenitic	Austenitic	Austenitic	Austenitic	
Magnetism						
Ferromagnetic	—	—	—	—	Trace	—
Perme- ability: As annealed	1.003	1.003	1.003	1.003	1.003	—
Perme- ability: Cold worked 10%	1.10	—	1.006	1.003	—	—
Specific heat						
C.g.s. units, 0 to 100°C.	0.12	0.12	0.12	0.12	—	—
(Mild steel = 1.00)	1.1	1.1	1.1	1.1	—	—
Thermal conductivity						
** C.g.s. units at 100°C.	0.0390	0.0385	0.0380	0.03 to 0.04	0.03 to 0.04	—
(Mild steel = 1.00)	0.33	0.32	0.32	—	—	—
C.g.s. units at 500°C.	0.0515	0.0528	0.0520	—	—	—
Thermal expansion per °F. × 1,000,000						
From 32 to 212°F.	9.6	9.3	9.9	8.3	8.8	8.8
(Mild steel = 1.00)	1.45	1.40	1.50	1.26	1.33	1.33
From 32 to 932°F.	10.2	10.3	10.8	9.6	9.4	9.3

Mechanical Properties at Room Temperature	18-8 Annealed	18-8 Cold Worked (Wire)	18-8 † Stabilized	18-12 Annealed	18-12 Cold Worked (Wire)	25-12 Annealed	25-12 Cold Worked (Wire)	25-20 Annealed	18-26 Annealed
Ultimate strength, 1000 psi.	80 to 90	105 to 300	85 to 95	80 to 90	105 to 275	90 to 110	110 to 270	80 to 110	90 to 110
Yield point, 1000 psi.	40	60 to 250	40 to 45	40	—	40 to 60	65 to 230	35 to 65	45 to 50
Elastic modulus, 10^6 psi.	29	—	—	—	—	—	—	—	30±
Elongation, % in 2 in.	60	—	55	60	—	50 to 35	—	60 to 45	35 to 30
in 10 in.	—	50 to 2	—	—	50 to 2	—	35 to 2	—	—
Reduction of area, %	70	65 to 30	55	65	65 to 30	60 to 45	55 to 20	—	45 to 35
Impact, ft-lb.; Charpy	—	—	77	—	—	—	—	40 to 80	—
Izod	75 to 110	—	—	—	—	—	—	—	50 to 90
Fatigue endurance limit, 1000 psi.	47	50% of ultimate		—	—	—	—	—	—
Hardness, Brinell	135 to 165	170 to 460	150 to 185	135 to 165	170 to 380	150 to 185	170 to 375	130 to 190	160 to 185
Rockwell	B-75 to 85	C-5 to 47	B-80 to 90	B-75 to 85	C-5 to 40	B-80 to 90	C-5 to 40	—	—
Erichsen value, mm.	11 to 14	—	—	—	—	—	—	—	—
Stress in psi. causing 1% "creep" in 10,000 hr. at 1000°F.	17,000							—	7,000
1200	7,000							7,400	—
1350	3,000							3,300	—
1500	850							1,100	—
1600	—							—	1,900
Scaling temp., °F.	1650		1650	1650		2100		2000	1650
Initial forging temp., °F.	2200		—	As for 18-8		2200 to 2300		—	1950
Finishing temp., °F.	Not under 1600 to 1700		—	As for 18-8		Not under 1600 to 1700		—	—
Annealing treatment	Heat at 1900 to 2000°F. and quench		††	As for 18-8		Heat at 2000 to 2150°F. and quench		—	As for 18-8

* Electrical resistance of cold worked 18-8 ranges from 70 to 82 microhms per cm. cube

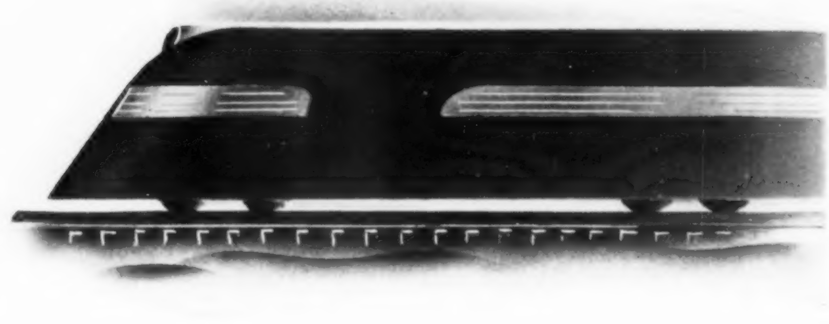
** Thermal conductivity is measured as calories per sq.cm. per sec. per °C. per cm.

† Small cold reduction, followed by anneal at 1400°F. and quench

†† Final heat treatment must consist of 2 to 4 hr. soak at 1550°F.

NICKEL

WIDENS THE SCOPE OF STAINLESS STEEL APPLICATIONS



The phenomenal expansion in the use of the stainless steels reflects the remarkable adaptability of this interesting family of alloys.

When added to alloys of this type, nickel improves ductility, assuring satisfactory response to the ordinary fabricating operations. It refines the grain and increases resistance to impact and creep at elevated temperatures. Nickel also enhances the corrosion resistance properties and thereby extends the field of usefulness of stainless steels.

Stainless steels of the 18-8 variety respond well to cold work and ultimate strengths in sheet and strip around 200,000 p.s.i. are readily attainable. In this condition, they can be flanged and bent and are easily welded.

The high strength-to-weight ratio so obtainable has led to the use of stainless steels of this type for a wide variety of structural applications... notably, for high-speed railroad trains, passenger car bodies, deck structures and masts on ships, and strength members of airplane wings and fuselages.

Consultation on problems involving the use of nickel and its alloys is invited.

THE INTERNATIONAL NICKEL COMPANY, INC.

67 WALL STREET, NEW YORK, N. Y.

Last winter the Cleveland Chapter, A.S.M., held a series of round table conferences; one was devoted to electroplating, wherein was stressed the necessity of sending nothing but scrupulously clean work into the plating tanks. This article tells how it can be done

Cleaning Before Plating

In the art of electroplating, more so-called plating troubles can be traced to the treatment of the base metal before plating than to any other factor. One may have the finest plating bath in the industry and the most skilled operator in charge — but give him dirty base metal and the finished plating job will be highly unsatisfactory. These faults may not be apparent at once but beyond a doubt they will bob up to plague the plater before many weeks have passed. Hence the importance of adequate cleaning methods.

The cleaning of metals before plating (with particular reference to ferrous metals) can be roughly subdivided into three steps. The first step is to remove the oil or grease. The second step is to remove the rust and scale. The third is to remove the carbon smut.

Grease and oil on a metal part coming into the plating department may be any one or a combination of various substances. It may be a straight mineral oil of the light body type such as slushing oil; it may be a heavy mineral oil such as often found in drawing compounds; it may be a vegetable oil which constitutes a number of drawing compounds and soluble oils; it may be an animal oil such as found in buffing compounds and some quenching oils. Job shop platers must of course contend with all types which makes it very difficult. Fortunately in a shop such as Firestone Steel Products', it is possible to control the types of oils to suit the cleaners rather than attempt to control the cleaners to suit the oils. This is distinctly recommended as being by far the lesser of the two evils.

By Terrence A. O'Neil
Firestone Steel Products Co.
Akron, Ohio

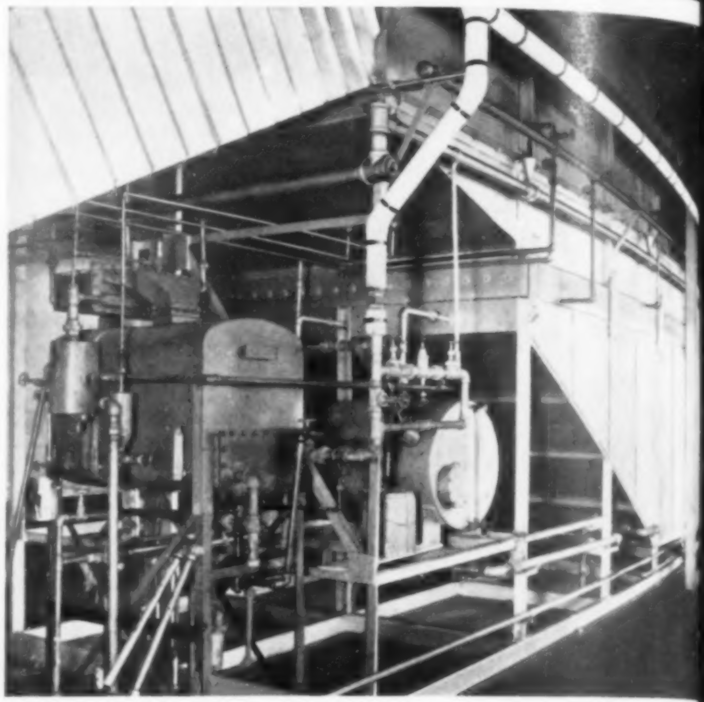
The first step in metal cleaning — that of removing the grease and oil — can be considered in three principal subdivisions. The first and most commonly known is that of solvent degreasing.

Solvent Degreasing

This merely implies the soaking of the oily article in some organic liquid in which the oil in question is soluble. Familiar solvents of this nature are gasoline, benzene, xylene, and carbon tetrachloride. In favor of this method is the speed with which a relatively clean article can be produced; furthermore such solvents will dissolve almost all types of greases encountered. In some cases where extremely heavy films of tenacious grease are encountered, particularly those having had a chance to "set up" or partially oxidize from long standing, it is advantageous to remove the worst of it in a solvent cleaner irrespective of the final cleaning methods employed.

Several undesirable factors are involved in solvent degreasing, however, which tend to decrease its popularity. With the exception of carbon tetrachloride and related chlorinated hydrocarbons, most of the solvents are combustible and consequently present a fire or explosion hazard. Also there is the question of toxicity; the fumes of benzene are definitely

Exit Side of Large, Conveyorized, Vapor-Type Degreaser Used for Cleaning Automobile Fenders and Other Sheet Metal Parts. The continuous still for removing solids and oil contamination from the solvent is shown in the foreground. Photo Courtesy Detroit Rex Products Co.



poisonous and the effect of the vapors from some of the other mediums on the human system is open to dispute. (In all fairness to the promoters of various solvent cleaning methods let it be said that they can present very convincing evidence that for particular solvents, at least, the toxic effect is more myth than fact.) From the plater's viewpoint simply immersing a grease-coated article in a solvent is not adequate because the grease is merely diluted and not entirely removed; the dirtier the solvent becomes with continuous use the heavier the film of grease becomes as the article to be cleaned is withdrawn and the adhering solvent allowed to evaporate. Finally, solvent degreasing is too expensive unless the volume of production warrants the installation of suitable equipment for distilling the solvent from the accumulated grease and dirt for re-use.

Before leaving the subject of solvent degreasing, one method should be mentioned which is particularly good for handling heavy coatings of mineral oil that would be difficult to clean in alkali alone (as later to be described). The work to be cleaned is soaked, brushed or sprayed with a mixture of light bodied solvent and an emulsifying agent. The solvent penetrates the grease and oil, loosening it and carrying the emulsifying agent into the film, there to become intimately mixed with the dirt and oils. The work is then rinsed in rapidly flowing fresh water, the dirt is immediately deflocculated and the oils carried away in emulsion. This treatment should be followed with a short alkaline soak to remove the final traces of oil to give a clean water break.

Vapor Degreasing

As the second subdivision in methods of grease removal, the type of cleaning known as vapor degreasing is mentioned. As a matter of fact, this also is solvent cleaning, but the refinement of the procedure makes it worthy of separate consideration.

In this instance a more elaborate equipment is employed, consisting in the main of a metal receptacle with a reservoir for the solvent in the bottom which is heated by steam, gas or electricity and a cooling jacket at the top for condensing the vapors. The closed space between the surface of the heated solvent and the cooling jacket is saturated with hot vapors. The metal to be cleaned is passed through this region and, being comparatively cold, the vapors condense on the surface of the work, dissolve the oil and grease and drip off into the reservoir below.

Any inorganic dirt on the work, not being soluble, of course is not removed. However, equipment can be had that combines both solvent degreasing and vapor phase degreasing, and will thoroughly clean almost any combination of dirts and greases. In them the work is soaked in the boiling solvent where all of the grease is thoroughly loosened and the included dirt is carried away mechanically by the rapid movement of the boiling solution. This step is followed by a rinse in cold, clean solvent to cool the work and further dilute any remaining grease. Then the work is finally subjected to the vapor treatment mentioned before. There is no doubt but that this is highly efficient and thorough.

One of the advantages of vapor degreasing is that the work is absolutely dry when it emerges from the vapor and can be stored for short periods without danger of tarnishing. Another factor in favor of vapor or solvent-vapor cleaning is that such soft metals as zinc, lead, aluminum die castings, copper, brass can be treated without

danger of corrosion or staining, as often occurs in alkaline cleaners. Solvent plus vapor degreasing is probably the most rapid method available, $1\frac{1}{2}$ to 2 min. being the total elapsed time for going through the three phases described. There was at first some criticism against the boiling of chlorinated hydrocarbons, as it was claimed that they decomposed to liberate hydrochloric acid, but this objection has since been overcome by increasing the purity of the solvent or by adding proper inhibitors where necessary.

Alkaline Cleaners

The third class of metal degreasing, and no doubt the most widely used, is the alkaline cleaning bath. Any attempt to describe the hundreds of combinations of various alkalies and soaps in use would be beside the point here. Irrespective of the alkaline cleaner used it is sufficient to say that its cleaning action depends mainly upon three reactions. First is saponification, where the free active alkali in the solution attacks the animal and vegetable oils to form water soluble soaps; second is emulsification, where the soaps or soap substitutes attack the mineral oils, breaking up the film on the work and causing it to be suspended in the cleaning medium in tiny globules; and third, the mechanical action obtained either by rapidly agitating the solution, by introducing some insoluble ingredient in the bath to impinge on the work, or by employing an electric current. There are other phenomena occurring in alkaline cleaners of greater or smaller importance, but broadly speaking they reinforce or improve one or all of the main functions.

Electrolytic Caustic Tank With Canvas Hood-Curtain Raised to Show Exit End and Hot Water Rinse. Note break in electrode bars; work is cathodic throughout the tank, but just before leaving the solution it becomes anodic

For practically all alkaline cleaners to be used in heavy duty tanks the principal ingredient is caustic soda. To this is usually added soda ash, tri-sodium phosphate, sodium silicate and not uncommonly a little soap. The market is swamped with hundreds of good, bad, and indifferent proprietary cleaners. Every distributor has some advertising point, or points, which he stresses with great eloquence. However, when actual chemical comparisons are made, it is found that basically they are much alike, composed essentially of the ingredients mentioned above in varying amounts to obtain the causticity desired for definite cleaning purposes. In addition, several pre-mixed cleaners contain appreciable amounts of insoluble substances in water to serve as scrubbing agents and to assist in the dispersion and suspension of the solid dirt and oils. These types of cleaners are made up in solutions of from 3 to 8 oz. per gal. and used as hot as they can be held, usually near boiling.

Those who desire to do so may mix their own alkaline cleaners and obtain highly satisfactory results. Where the cleaning bath is under chemical control this method is probably the more economical, because when one of the components of the bath becomes exhausted it can be added individually rather than adding all the components as would be necessary in a pre-mixed cleaner. It is not the purpose of this discussion, however, to favor one method over the other. As a matter of fact, both may properly be used; we have proved the superiority of the one over the other for specific jobs.

When cleaning is to be done merely by soaking the article in a solvent, the equipment required is very simple. A steel tank provided with closed steam coils and an air line for agitation is all that is required. The work may be racked or stacked in baskets in a proper manner and lowered into the solution. The time required depends directly upon the nature of the grease and the efficiency of the cleaner.

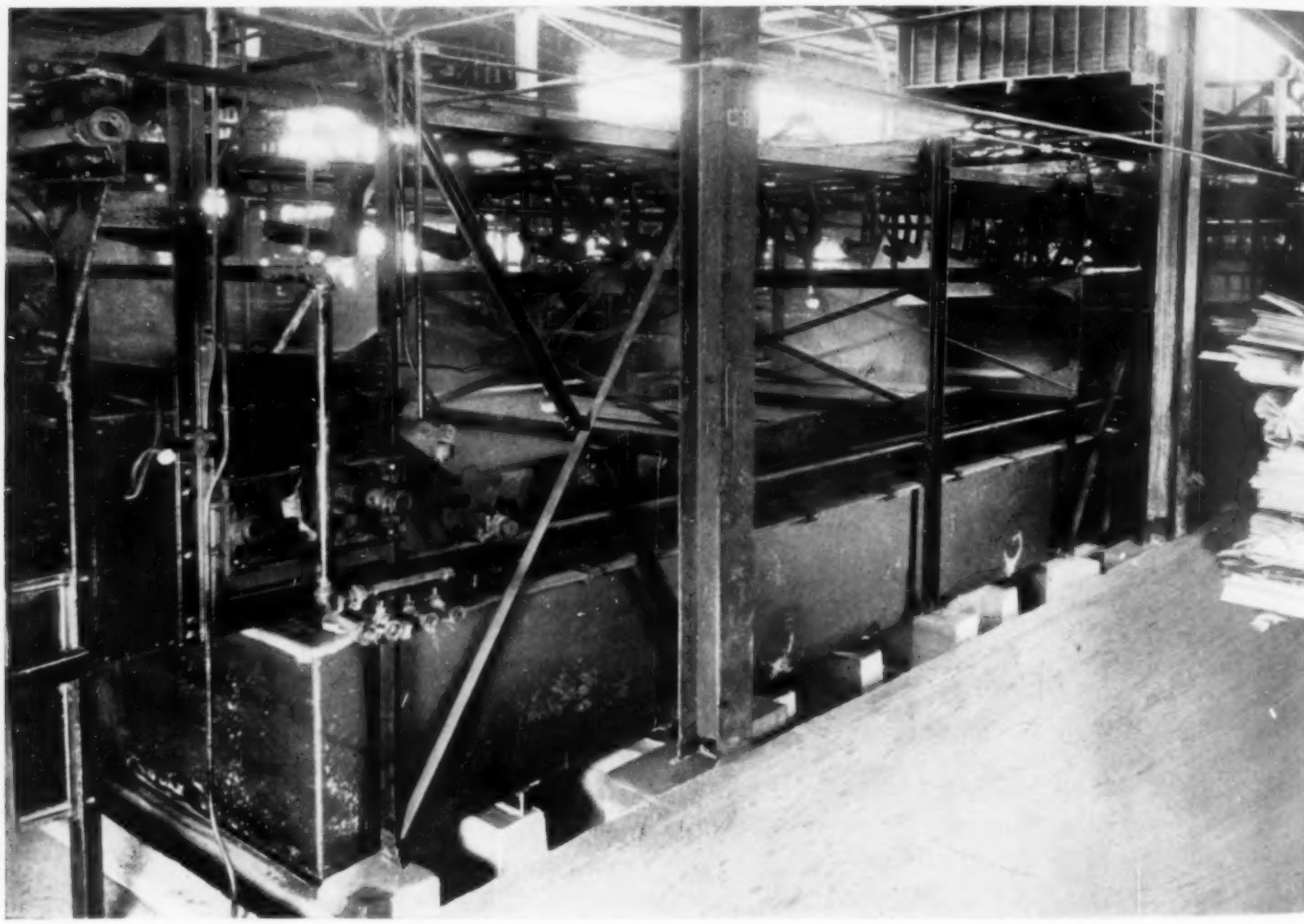
Electrolytic Cleaners

The efficiency of alkaline cleaning baths is greatly enhanced by the application of direct cur-

rent. Although cathodic cleaning is the practice at Firestone Steel Products Co., and is superior for our conditions, there are some who believe that anodic cleaning in alkaline solutions is somewhat better.

Cathodic cleaning — that is, connecting the work to the negative pole — is particularly effective because of the scrubbing action of the hydrogen gas liberated at the work. Rather high current densities are employed, (40 to 60 amperes per sq.ft.) so that the volume of hydrogen is quite copious. This localized violent action loosens and dislodges the grease and dirt which is then saponified or emulsified, as the case may be, and carried away into the solution. It is necessary to guard against metallic contamination in this type of bath because any metals present, such as copper, lead, tin, iron and zinc will plate out on the work.

Some operators have specific reasons for preferring the work to be the anode or positive electrode. In this case the action does not depend upon the scrubbing action of the evolved gas but rather upon a "plating off" effect; the metal tends to go into solution. To prevent too severe an attack on the work it is necessary to keep the current density much lower, usually about 20 amperes per sq.ft. Soft metals such as copper alloys, lead, tin and zinc cannot be cleaned by this method if the smoothness of the surface is important because the etching action of the ionized solution is too severe.



Conveyorized Sulphuric Acid Tank for Pickling Rim Sections and Flat Bar Stock

The composition of the baths used in electrolytic cleaning is about the same as for soaking baths except they are usually not quite as concentrated. We have been quite successful in cleaning drawing compounds from steel stampings with about 3 oz. per gal. each of caustic soda and soda ash. On several occasions soluble sodium silicate mixtures have been used which,

when reinforced with a little caustic, cleaned excellently, but these solutions gave a particularly tenacious foam which saturated itself with escaping hydrogen and exploded with terrific violence whenever a spark from a short circuit or a rocking contact ignited it. No damage would be done, but it was disconcerting and nerve-racking, to say the least, when approximately 100 sq.ft. of foam would explode beneath one's nose when least expected!

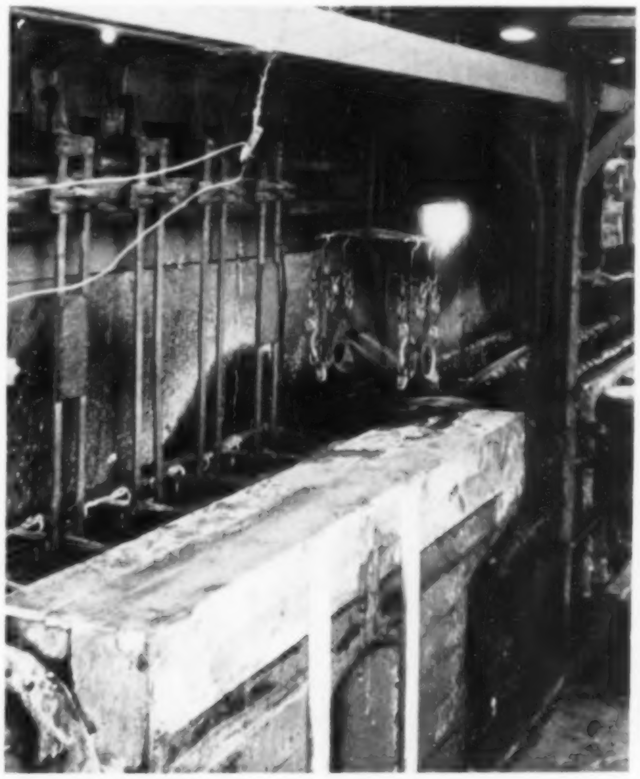
In the cleaning of steel inserts for rubber bumpers and motor supports, tri-sodium phosphate was formerly used in small concentrations in our electrolytic cleaning bath, but under certain conditions it tended to stain the work, probably with an iron phosphate coating, which made the steel immune to subsequent pickling operations. Since then its use has been abandoned, apparently with no decrease in the efficiency of the cleaner. It is not necessary to add any soap to our mixture because we are constantly cleaning a large volume of work coated, in part, with vegetable oils that are converted to soap by the free alkali. In other plants the work to be cleaned may be coated entirely with mineral oils which do not saponify, and additions of soaps or soap forming substances would then be necessary for an adequate job.

Removing Scale and Rust

The second step in the cleaning of a metal before plating is the removal of mill scale and rust. There are two principal methods; the first is some mechanical method such as sand, steel shot, or grit blasting. As the name implies the rust and scale is literally blown from the surface of the work. Where a polished surface is not required after cleaning there is no doubting the efficacy of this method. However, blasting, grinding and other mechanical means are comparatively expensive and not applicable to a number of the parts which the plater is called upon to process, because of their size and shape.

The second method, and most commonly used, is the chemical means of treating with acids — usually called pickling. This was exhaustively described by Messrs. McCollam and Warrick in last month's Metal Progress. In pickling the adhering oxides are either dissolved in the acids or sloughed off by dissolving the metal underneath. For ferrous metals the most common acids are sulphuric and muriatic. Sulphuric acid is cheaper, muriatic acid is faster, has less tendency to pit the work and is effective at lower temperatures. Whereas muriatic acid can be used in concentrations up to 50%, sulphuric acid loses its efficiency if stronger than an 18 to 20% solution.

Sulphuric pickles are always heated to at least 140° F., with 160 to 180° F. being common practice, while jobs that require a particularly drastic pickle in a short time may require temperatures in excess of 200° F. High temperatures are to be avoided whenever possible, however, as the hotter the bath the worse the fuming. The control of temperature is important. Roughly, a 20° F. increase in temperature will double the speed of pickling.



Electrolytic Bright Dip at End of Cleaning Operation. The work is anodic at a current density of 100 to 125 amperes per sq.ft. in a 50% cold sulphuric acid solution. The carbon film left on the metal surface by the pickling operation is removed by this treatment

Other acids or combinations of acids are used for specific pickling or etching purposes. Hydrofluoric acid is used alone, or more commonly with sulphuric acid, for dissolving sand or silicious scale from castings. Nitric acid pickles are valuable for certain alloy steels, copper, copper alloys, and others. A combination of nitric and hydrofluoric acids has been found effective for

removing scale from stainless steel. Mixtures of sulphuric, nitric, and muriatic acids are also commonly used for scaling brasses.

Electrolytic Pickling

Electrolytic pickling is commonly used to hasten the job and for other specific reasons. Whether the work is made the anode or the cathode depends entirely upon the composition of the metal and the degree of etching anticipated. Anodic pickling is usually the more drastic and pitting will be encountered if not carefully controlled. Another disadvantage, unless previously anticipated and allowed for, is the formation of passive films. When the work is made the cathode the large volume of hydrogen gas liberated at the work helps materially to lift the scale. Also the reducing effect of this atomic hydrogen is a powerful medium for converting the oxide present to its respective metal.

Recently alternating current has come into prominence; it is particularly adapted to the continuous pickling of steel strip. A sulphuric acid bath of approximately 15% strength is used with two electrodes submerged in it between which the steel strip is drawn. At 10 to 15 volts a current density of 100 to 150 amperes per sq.ft. is generated. This is said to be a very rapid method for removing rust and scale.

The third and final operation essential to proper cleaning of metals before plating is the removal of the smut left by the pickling operation. This smut may be any insoluble material in the metal remaining upon the surface as the soluble portions are dissolved away. The most common example of this smut is the carbon film which forms on ferrous metals while pickling.

In the majority of shops this is removed mechanically. If the work is of such a size and shape that it can be readily tumbled it is dumped into a rotating barrel containing steel stars, sand, or any abrasive material, and the smut removed by the scouring action of the abrasive. Usually the barrels rotate in a solution of some mild alkali or a soap to assist in the cleaning action and to prevent the work from rusting. Large articles may have to be scoured by hand with wire wool or steel brushes.

Chemical methods are also employed for removing the films left by the pickling operation. An electrolytic bright dip made up of 35 to 50% sulphuric acid maintained below 80° F. by suitable cooling coils is an effective means for removing carbon from steel. The work is made the anode; the current density required is about 100 to 150 amperes per sq.ft. Under these conditions the work is rapidly rendered passive, pickling ceases and the carbon is oxidized or swept away in the oxygen evolved.

Numerous other bright dips are employed for non-ferrous metals. A flash dip in nitric acid is effective for copper. Brass can be brightened by a number of mixtures such as muriatic acid and zinc chloride, or a dilute mixture of nitric, sulphuric and muriatic acids. Dilute nitric acid is also an effective brightener for stainless steel.

In addition to the mechanical cleaning and the use of various acids it is advantageous to finish cleaning, particularly ferrous metals and brasses, with a cyanide strip. For this purpose an alkaline sodium cyanide solution is used consisting of about 2 oz. per gal. each of sodium cyanide and caustic soda. Direct current is employed with a suitable reversing mechanism at the generator so that the polarity is changed at definite intervals. The polarity is reversed every 30 sec. in our stripping tanks — that is, the work is the anode for 30 sec. and then it is the cathode for 30 sec. This combined action will reduce any oxides remaining and plate off the metallics. Considerable gassing occurs in this solution; this also tends to sweep away any loose carbonaceous material which may have escaped the previous cleaners.

The work should now be scrupulously clean and is ready for plating.

Terrence A. O'Neil

Ever since graduation, B.Sc. in chemistry from University of Nebraska, 1930, O'Neil has been studying the cleaning and plating of tire rims and other steel stampings for the Firestone Steel Products Co.

Notes on large-scale applications in the Chicago stockyards for packing equipment where resistance to meat juices, water and disinfectants is necessary during continuous and hard usage

Meat Packers Use Stainless

In the meat packing industry there are special reasons for paying close attention to the condition of meat-handling equipment over and beyond the normal processes of rusting. Of course, the latter is of great importance, as anyone who has left some tools out in the rain, or who has had to renew downspouts on his home, or corrugated siding on his shop, well knows. Indeed, it is reliably reported that more steel converted itself into rust during the depression years than was converted from iron ore by man in the entire world in the corresponding time.

Viewed in this light, the extra cost of the truly stainless steels becomes an eventual economy. The meat packing industry was one of the first to realize this, and adopt the metal for many purposes. If it had been available 20 or 30 years ago, the packers would undoubtedly have determined its possibilities and installed it in equipment a generation ago.

As a matter of fact, stainless steel is a relatively new metal, and while it was discovered in the period just prior to the War, it was not manufactured in this country in sizeable amounts until about 1925. There was then the matter of education — of convincing equipment manufacturers they should build machinery from it, and telling the consuming industries that such machinery should be bought. There is always a period during the introduction of a new method, a new idea, or a new material when there is a decided lull. The users must be convinced that it is a superior method or a better product than their present ones. Time is required for tests and experimental work. And then, to be sure that the results were not accidental, tests are repeated. The machine and equipment builder must learn the fabricating characteristics of the metal. Sometimes new shop tools were needed to work stainless steel properly, for it is tougher and twice as strong as common steel and many times copper, aluminum and other non-ferrous alloys.

By Curtis C. Snyder
Sales Engineer, Alloy Steel Division
Republic Steel Corporation, Massillon, Ohio

This dormant period for stainless steel ended about 1929. It has passed adolescence and is now mature. Fabricators have placed themselves in the position to produce high quality stainless steel machinery. There is scarcely a packing plant of any consequence that does not utilize it to a considerable extent and when further equipment is to be purchased it will be specified in stainless.

We, as representatives of the steel industry, have an interest in this, sincerely believing as we do that the greatest good for the greatest number will result when much of our present short-lived metal is replaced with enduring alloy. Consequently we made a careful survey of the packing plants in the Chicago region, endeavoring to find out exactly where stainless steel should be used and why, where other metals had failed in service or caused acute dissatisfaction, and where the ordinary steels and irons are plenty good enough. These data have been of utmost service both to us and our customers.

What are the properties of stainless steel that have made it so valuable to the meat packing

Extracts from an address before the Institute of American Meat Packers

plant, to the dairy and ice cream manufacturer, to the food and baking industries, as well as to numerous other industries not associated with foods and meats? There are a number of them, among which the most important are:

1. It does not rust or corrode in contact with meats, meat juices, or the substances used in the preparation of meats.

2. It does not impart a metallic taste, flavor or color to meat products.

3. It retains its bright, shining surface indefinitely. Cleansing as required for sanitation purposes is all that is needed. No polishing or scouring is necessary, as there is no rust or corrosion to remove.

4. It is entirely resistant to salt, brines, cleansers and sterilizers.

5. Because it is a tough, hard metal, it is not subject to wear, denting or breakage.

6. It is not a plated metal, hence there is no coating to wear thin, exposing a corrodible metal beneath.

7. And finally, in view of the previous statements, it follows that the points nearest the pocketbook — namely maintenance costs — are greatly reduced. To those who have stainless steel equipment in service, this last remark is superfluous.

This is not the place to give a dissertation on the manufacturing methods. It is enough to say that sheet metal, plate, bars, rounds, pipe — all the common wrought products — are available in a series of high chromium-iron alloys and chromium-nickel-iron alloys. Chromium is the element that is ordinarily regarded as lending corrosion resistance to the alloy, as this property increases almost proportionately with the percentage of chromium present. A whole series of alloys is available in the range from 11% up to about 28% chromium; the members of this family which are very low in carbon have good workability and fair weldability; the members which are high in carbon include the excellent cutlery steels — true steels, hardenable by quenching and tempering.

Some difficulties with the plain 18% chromium alloys are avoided by adding 8% nickel, giving the well-known 18-8. This is the most popular one in the meat packing plants. It has greater corrosion resistance than the straight chromium types, and furthermore it has better fabricating properties, being more ductile, and lends itself better to welding. 18-8 also has very low carbon content, under 0.12%; even a lower limit in carbon should be specified when the equipment is fabricated by welding.

As seen in the table of physical properties on pages 56 and 57 of this issue of METAL PROGRESS, all the stainless steels in the annealed condition have yield points somewhere around 35,000 to 40,000 psi., and tensile strengths of 70,000 to 90,000 psi. When a hard temper is required, such as for conveying belts, springs, or similar parts, 18-8 can be furnished with 150,000 lb. tensile strength or higher. Hard, wear resistant parts are best made of the chromium-iron alloys with higher carbon, in the form of forgings or castings, properly heat treated.

Finally, some of the more important applications in American meat packing plants may be enumerated:

1. Several large plants have viscera tables, for use with hogs, beef and sheep, of the 18-8 type of stainless steel. Federal inspection requires that the tables be kept sanitary, and a non-corrodible material is desirable to resist the disinfectants used on the pans. The ease with which these surfaces can be cleaned is truly remarkable.

Pans, Chutes, Bins, Perforated Table Tops, Hangers and Piping, All of Stainless Steel. Work benches in hog casing department of Wilson & Co., Chicago

2. In the manufacture of sausage, the stuffing and linking tables are of stainless steel, as well as the stuffer worms, meat conditioning pans, patty tables, and sausage hanging and display racks.

3. Individual ham and meat loaf boilers.

4. Conveying belts, sorting and cleaning tables for a variety of uses.

5. Offal tables and chutes.

6. Bacon slicing tables.

7. Tables for the wrapping and packing of smoked meats.

8. Melting kettles, mixing machine blades and kneading table blades for oleomargarine.

9. Pork cutting: Ham trimming, skimming table, shoulder bench, and benches for boning pigs' feet.

10. Pork curing and salting tables.

At the start I mentioned that the annual toll due to rust and corrosion was about 67,000,000 tons of iron and steel or roughly three billion dollars per year. The meat packing industry is a heavy contributor to this "Rust Racket," as it has been so aptly termed. There is now a readily available means of putting a halt to these staggering losses. Stainless steel is the weapon; its value cannot be expressed any better than in the words of one of the engineering fraternity, who said, "I let stainless steel take care of the corrosion problems and I spend my own time operating the plant!"

During the Chicago Century of Progress Exposition, Countless People Saw the Armour "Red Heads" Packing Chipped Beef Into Cartons. Here is one of the Red Heads in the plant; the stainless table top reflects cleanliness

Rapid Fatigue Test

By J. W. Cuthbertson

Condensed from Carnegie Scholarship Memoirs British Iron & Steel Institute

THERE IS a fixed stress for a given material which can be repeated an infinite number of times at a given frequency without causing fracture, but if it is exceeded by a small amount failure will ultimately occur. In testing steels at room temperature, a basis of 6×10^{6} reversals of stress is standard practice, and hence, if the stress frequency is 2000 cycles per min., the shortest time for a test in the vicinity of the fatigue limit will be a little over two days. A similar test on duralumin would require nearly 35 days, and heated steel bars are in a class intermediate between these two extremes. Much study has therefore been given to rapid tests.

In the case of all materials so far examined by the writer, the discrepancy between the "rapid" fatigue limit to be described and the true endurance limit has proved too small to bear any practical significance. The trouble is usually not that the rapid test gives too high a fatigue limit, as is frequently asserted, but rather poor definition of the exact point.

In this work a cantilever test piece of tapered dimensions and long ends for chucking into the rotating and loading devices respectively is used. Deflection measuring equipment, accurate to 0.00001 in. is necessary. In the test the deflection of the rotating specimen is plotted against the load causing it, as the latter is increased by steady increments. For moderate loads this line is straight; the fatigue limit is deduced from the position where the line shows a slight bend or offset — the "yield."

As a result of tests, numbering some 250, on a variety of metals and alloys, both ferrous and nonferrous, it is concluded that the initial part of the load-deflection curve is never linear, the stress tending to increase more rapidly than the strain. The effect appears to be an inherent peculiarity of the method of testing, and in extent and duration will probably vary with different testing machines and different forms of specimen. When conducting a given test this erratic portion at the very start of the load-deflection curve is neglected, and with continuous loading the author has never experienced a subsequent recurrence.

To investigate the effect of variation in the loading rate on the accuracy of the rapidly determined fatigue limit, a number of tests were carried out on five steels, covering a wide range of loading speeds. The results are quite conclusive. There is clearly no advantage in reducing the rate of load increase below 0.5 lb. per min., the optimum conditions from

(Continued on page 86)

European Status of the Stainless Steels

Trend Toward More Complex Stainless Steels

SHEFFIELD, *England* — As in America, the so-called stainless steels used in England cover a rather wide range of chromium and nickel content, frequently with a considerable amount of other alloying metals. For convenience, the stainless steels used as high strength constructional materials may be grouped in three main categories: (1) Martensitic, (2) ferritic, (3) austenitic.

The martensitic steels in turn may be broadly subdivided into two groups having the following basic compositions: *(a)* 12 to 14.5% Cr, *(b)* 16 to 20% Cr, 1 to 3% Ni. Group *(a)* has not been appreciably modified for some considerable time. The lowest carbon variety (frequently called "stainless iron") is widely used for turbine blading while the higher carbon steels are used for surgical instruments, cutlery and other purposes which demand a sharp cutting edge and for general engineering use where materials having tensile strengths of about 90,000 to 150,000 psi. are required, and also as heat resisting steels which resist oxidation when heated to temperatures up to about 1400° F.

The *(b)* group with a little nickel has not yet been used, so far as I am aware, to any appreciable extent in America. It may be interesting, therefore, to note how it was evolved and to what extent it is used in this country:

About 12 years ago it became evident to us that the steels with 12 to 14% Cr had not sufficient corrosion resistance for a number of engineering applications. The austenitic steels which had only just been developed in England were also unsuitable on account of their softness. Extensive investigations were then carried out under my direction in the research laboratory of Brown Bayley's Steel Works, Ltd., and as a result, this firm produced in 1925 a steel called "Twoscore," containing roughly 18% Cr and 2% Ni, which possessed the desired greater resistance to corrosion and could be hardened and tempered to high strength together with good toughness.

In addition to its use in general engineering for purposes where the lower chromium steels were not completely satisfactory (as for steam and hydraulic fittings working through packings or in contact with copper alloys), it has become the standard steel for the construction of seagoing aircraft where material capable of being hardened and tempered and of possessing a high tensile strength is essential. It has a very much greater resistance to the attack of sea water than the lower chromium steels, hence its adoption by our Air Ministry.

As a matter of general interest, I might mention that this 18-2 steel has also been selected by leading architects for the strengthening and restoration of valuable old buildings; thus the massive chains which encircle the dome of St. Paul's cathedral in London, and those similarly fitted to the Church of the Holy Sepulcher in Jerusalem are made of it. When the renovations were carried out on these two famous buildings, support for the dome was deemed advisable in each case, and this martensitic steel was selected on account of its high corrosion resistance and high tensile strength. The chains on St. Paul's cathedral are each designed, I believe, to support a load of 1000 tons.

Ferritic alloys of the second main category are not very largely used in this country on account of their low notch toughness. An exception to this is the special "Brearley K" stainless iron with 16 to 18% chromium, made by Brown

Bayley's, which possesses a reasonable impact value and has been very largely used in this country and on the continent of Europe for nitric acid plant. Recently also we have supplied a large tonnage of this material in plate form for the construction of plant for the sugar industry. This special iron is probably more easily fabricated by boiler makers' processes than other types of corrosion resisting steels.

The ferritic alloys are used to a considerable extent as heat resisting steels; they have the advantage of being less affected by sulphurous gases than the nickel-containing steels, but, on the other hand, are considerably weaker than the latter at high temperatures. The chromium content of such alloys is adjusted to meet the service conditions and may be as high as 30%. Sometimes, additions of aluminum or silicon or both replace part of the chromium. In the case of wrought products the carbon content is generally held at a low figure, but in castings it may be as high as 2 or 3% when the chromium content reaches 30%. Such high carbon, high chromium castings are frequently used for furnace equipment (boxes, skid bars and the like) owing to their strength and resistance to abrasion.

With the possible exception of the cutlery type of stainless steel, the austenitic steels of the 18-8 type are probably the most widely used of all. Rather than list their important applications it is better to describe some recent trends in their development — chiefly in the production of steels free from intergranular corrosion effects (or "weld-decay-free" steels, as they are often called). Many firms over here are depending on the addition of titanium, the beneficial effects of which were discovered by Krupp. The contribution of our own firm to this end has been the use of silicon (up to 6%) as a means of preventing intergranular corrosion. We are regularly producing steel under this patent which is quite free from troubles due to "weld decay."

The silicon content of the steel has other very definite advantages; for example, it increases markedly the resistance of the steel at high temperatures to oxidation and to the attack of many acids. Again, it is well known to be difficult to produce a deposit of weld metal which will be free from intergranular corrosion when using a steel stabilized with titanium, owing to the readiness with which this metal is oxidized; silicon is much less readily oxidized and there is no difficulty in producing deposits of weld metal from the high silicon 18-8, which are themselves free from intergranular corrosion.

It is therefore being widely used either cold rolled or fully softened for aircraft purposes, as turbine blading particularly where salt contamination of the boiler feed water is liable to occur (since the steel is exceedingly resistant to such corrosive conditions), as equipment for the chemical industry where its superior acid resistance as compared with ordinary 18-8 steels is being recognized (in several cases, it is successfully replacing molybdenum-containing steels), and as a constructional material in many other industries — dairy, brewing and the like — where a stainless steel that can be used in the welded condition without subsequent heat treatment is required. It is also finding extensive application as a heat resisting steel.

For certain purposes in the chemical industry, steels of the 18-8 type containing up to about 4% molybdenum are used. Sometimes the molybdenum content is as low as 1% or 2%, though the advantages obtained are then not nearly so marked and in my own experience, results equally as good can be obtained at less cost by the use of the above-described high silicon 18-8. On the other hand, the properties obtained with a molybdenum content of about 4% are very valuable and during the last twelve months we have supplied several tons of it for plant subjected to the attack of acetic acid under particularly severe conditions. Incidentally, we are able to make this steel so that it can be used as welded without subsequent heat treatment.

Austenitic steels are also widely used for heat resisting purposes, sometimes under considerable stress, the actual composition being adjusted to suit requirements. Frequently silicon or tungsten or both are added, in addition to chromium and nickel, to give increased strength or resistance to oxidation. Some typical values in regular use are:

(a) Cr 12%; Ni 12%; W 2 to 2½%; Si 1 to 1½%.
(b) Cr 20%; Ni 8 to 12%; W 3 to 4%; Si 1 to 2%.
(c) Cr 18 to 22%; Ni 8 to 12%; Si 1 to 3%.
(d) Cr 25%; Ni 20%; Si 1%.

Such steels are selected where strength at high temperatures is an important factor, as they are superior in this respect to the ferritic alloys. They also have the advantage of being much tougher at ordinary temperatures than the latter alloys and also more easily weldable. On the other hand, they are liable to attack by sulphurous gases and when these conditions may be met in service, it may be necessary to use the ferritic alloys even at some sacrifice in strength.

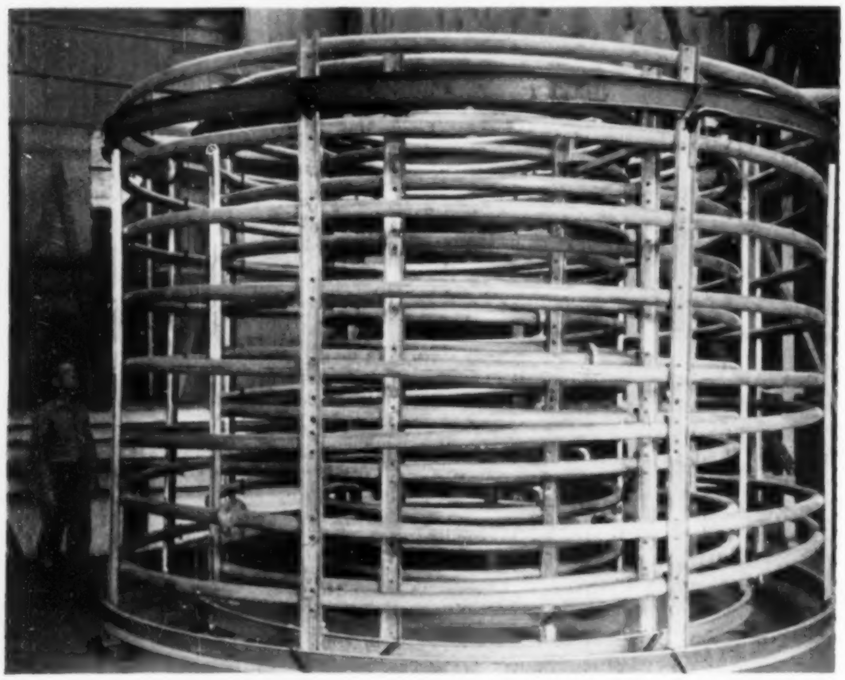
J. H. G. MONYPENNY

Low Carbon, High Chromium Alloys Perfected in France

PARIS, *France* — There have been no essential changes in the chemical composition of the various alloys classed as stainless steels and produced in France. They have been of the same general types as those used elsewhere, but their uses did not develop uniformly in all countries.

One of the most important alloys is, of course, the 18% chromium, 8% nickel steel. No important new application might be cited other than equipment for chemical and explosive factories, where a modification containing considerable molybdenum has been installed. This additional alloy has corrected certain difficulties which have been met in the use of plain 18-8 under conditions of both corrosion and erosion by liquids or gases in motion.

A notable development of the extra soft, high chromium alloys has recently occurred. In the ferritic alloy containing 17 to 18% chromium with less than 0.10% carbon, a number of applications of seamless tubes have been made in nitric acid plants. Such ferritic alloys are notable for their ease in working. For instance, table ware such as spoons and forks made of low carbon 15 to 16% chromium steel can be stamped, embossed and coined much better than 18-8.



Attemperator Coil for 38,000-Gal. Yeast Propagator. Fabricated from 1000 ft. of stainless tubing

Some difficulties are met in the welding of these ferritic steels because of the large grain growth which occurs which cannot be corrected by subsequent heat treatment. Studies now under way are leading to the solution of this problem in the way of using brazing materials which permit welding without passing 1400° F., which is below the ordinary recrystallization temperature.

An important recent installation of stainless equipment has been the nitric acid factory at the Kuhlmann plant of the Aciéries Electriques d'Ugine.

ALBERT PORTEVIN

18-8 Is the Favored Stainless Alloy in Germany

ESSEN, *Germany* — Progress of stainless steels in Germany lies in the expanding number and variety of applications rather than in any revolutionary changes in composition. The chromium-nickel steels have always been the favorite. They found their first important applications in our heavy chemical industry and, contrary to the trend of events in the United States, spread to general purpose applications in the food industry, for architecture, automobile construction, household equipment and art forms. So far, however, we have not used fast spot welding to any great extent for building structures, vehicles and aircraft of cold rolled stainless strip.

Some notably large installations have been made by the chemical industry. We might mention absorption towers 20 ft. diameter and 100 ft. high for the nitric acid industry, mammoth vessels for separation of fats under pressure, complete pressure cookers for the conversion of wood into cellulose, and furnaces for the synthesis of ammonia by the Claude process operating at 1000 atmospheres and 1000° F.

No substantial changes in the composition of the stainless steels have been made in the past year and a half. In general, 18% chromium, 8% nickel with carbon content less than 0.07%, or with carbide-forming additions such as titanium, tantalum or columbium to prevent intercrystalline corrosion, now makes up the largest percentage of the total production. Furthermore, 18-8 steels with additions of 1 to 5% molybdenum are becoming more and more important; excellent results are had with them, for example, in resisting hypochlorite solutions. As to heat treating, a low temperature anneal at about 1200° F. of the stabilized steels, such as titanium-

bearing 18-8, is of interest in raising the tensile strength and particularly the yield point. Because of the titanium content there is no danger of intercrystalline corrosion in later service.

Molybdenum is also being added to the plain chromium steels for its favorable influence on fatigue strength. We have also confirmed the grain-refining action of additions of nitrogen.

In accordance with the above facts, a widespread application is opposed less by technical difficulties — for here the limiting possibilities are pretty well known — than by the cost of the alloying elements nickel, chromium and molybdenum which are almost entirely imported. It is thus a problem of which we in the Krupp organization, as steel producers, cannot judge conclusively, and over which we have little influence. In this direction lie attempts to substitute manganese for nickel and to economize in the use of the standard 18-8 by increased use of bimetals.

One of our associates, P. Schafmeister, has published a discussion of these problems in *Die Chemische Fabrik* last October. Since nickel is, to us, relatively more expensive than chromium, most efforts have been expended on economizing in its use. Substitution of the ferritic 17% chromium steels for the 18-8 used in nitric acid equipment is quite logical from the viewpoint of corrosion resistance, but the difficulties of fabrication and welding are so much greater that this will be avoided until absolutely necessary.

Entirely new alloys have also been investigated, wherein all or part of the nickel in high chromium-iron alloys has been replaced with manganese. Manganese, however, is not as potent as nickel in changing the body-centered ferrite of chromium-iron into face-centered austenite, and it is therefore necessary to put in proportionately more of the alloy and also to raise the carbon content. Under certain conditions considerable delta iron (ferrite) is formed, but neither the delta nor the gamma solid solution seems very stable on long annealing. An iron-chromium compound, first observed in 1927 and called "B constituent" by Bain and Griffiths, will precipitate in these manganese steels at 900 to 1500° F., and as this is hard and brittle it causes considerable loss of ductility and the steel is not useful in that temperature range. Since corrosion resistance in boiling HNO_3 is lower, as well as oxidation resistance, the Cr-Mn steels cannot in any way be regarded as having the same excellent properties as 18-8 Cr-Ni, and direct substitution cannot be made. It remains to be proven whether the new steels will show any advantage in specific or new applications; 18-8 will undoubtedly remain the most reliable alloy for most uses.

(In passing, we might voice a warning that while the general corrosion resistance of "stainless steels" is very frequently judged by their behavior in boiling concentrated nitric acid, one should not generalize too much on the results of such a test and come to far-reaching conclusions as to the behavior of the alloy in other corrosive conditions.)

When it comes to oxidation resistance, chromium steels are equally as satisfactory as the Cr-Ni steels. Silicon and aluminum are the addition elements which are valuable here and deserve special attention since both are produced in Germany; although aluminum is manufactured from foreign bauxite, it is done very economically. When comparing the scale formed on various chromium steels containing 0.5 to 1% Si with those having 2 to 3% Si after heating in air at various temperatures for 120 hr., the 2 to 3% Si steels are in all cases superior. Aluminum has the same effect; 3% is sufficient to prevent measurable loss in weight in a 6% Cr steel after 120 hr. in air at 1500° F., and resistance to many other hot gases is in proportion. However, the high aluminum steels present certain difficulties in production and fabrication.

Silicon also increases acid resistance and some cast alloys contain as high as 15 to 16%.

The 5 to 6% chromium steel with 0.5% titanium is to be recommended for applications involving hot hydrogen gas under high pressure, such as for ammonia synthesis or hydration of coal, tar and mineral oils. Carbon steels tend to decarburize and lose ductility in such applications. These Cr-Ti steels are also of great utility to the petroleum industry.

We have also given much attention to the production of sheet, plate and tubes where one or both sides of a carbon or low alloy steel is sheathed in stainless.

Three factors are of particular importance in such construction: (1) Heat transfer is poor if even the thinnest layer of air separates the coating from the base metal. (2) A strong bond between the layers is required for bending and fabricating. (3) Differences in coefficient of expansion must be taken care of; ferritic steels have the same temperature coefficient as mild steels but austenitic steels are about 50% higher.

Bimetals or overlays are made in various ways. A slab of 18-8 will weld to mild steel by hot rolling if heating is done so as to exclude air at the cleaned contact surface. A more efficient

method is the casting of mild steel about preheated 18-8 slabs placed in the mold. For tubes, pierced bar inserts would be used and the exterior cast on and the composite casting then be rolled or drawn to size. High alloy materials can also be built up by welding, the welding being done either before rolling or later on a fabricated surface. Fabricated linings of stainless steel may also be welded to a jacket by spot welds at intervals, or by shrinking or expanding of tightly fitting cylinders.

No important failures in the use of stainless steels have occurred in recent years, although minor troubles have occurred now and again in the hands of purchasers, mostly due to their lack of care or knowledge of the range of possible applications. One example will suffice: In some condensers operating with brackish water, sufficient expansion was not provided for. As a result of the chloride content of the water, pitting occurred and the tubes cracked due to the temperature stresses and leaked through pitted areas.

BENNO STRAUSS
EDUARD HOUDREMONT

Changes in Austenitic Steels on Tempering and Annealing

UNIEUX, *France* — In the March issue of METAL PROGRESS, page 70, Jacob B. Friedmann writes from Moscow concerning a phenomenon of irreversible contraction produced in valve steels during a long stay at high temperature, and which he thinks has never yet been described.

As a matter of fact, it is but one phase of the general reactions of tempering discussed by Chevenard and Portevin in their "Contribution to the Study of Tempering of Quenched Steels" (*Revue de Métallurgie*, 1930). In this particular article they describe an investigation of two steels, one containing 1.5% C and 2.05% Mn, and the other 1.5% C and 2.25% Cr, both previously hyper-quenched (that is, *hyper-trempe*, from a high temperature) and attributed the contraction to a precipitation of cementite, revealed on cooling by a Curie magnetic point at about 150° C. (300° F.).

Their conclusions, which are useful in appraising our own data, may be summarized thus: All the phenomena observed in tempering hypereutectoid austenite may be collected into three elementary reactions, as follows, which are superposed on one another and intermingle:

I. Supersaturated gamma solution → cementite + gamma solution with less carbon.

II. Gamma solution → cementite + martensite (alpha solution).

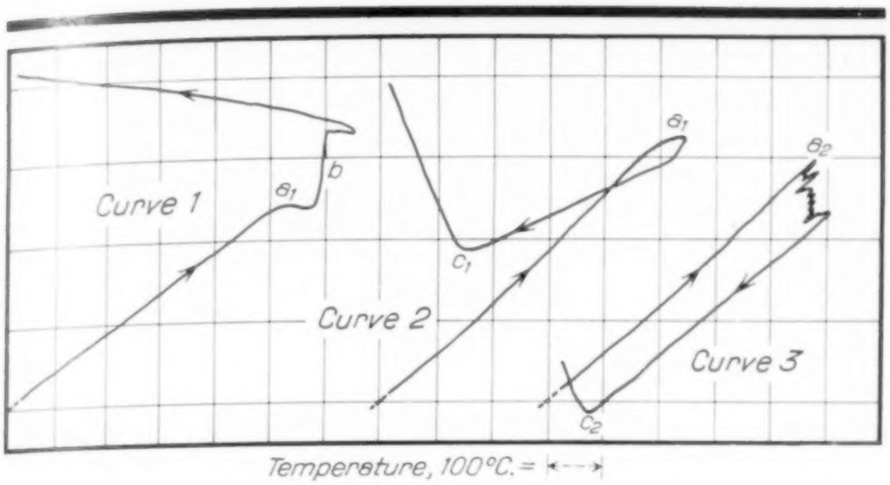
III. Gamma solution → martensite.

Reactions I and II occur during the actual tempering, while reaction III takes place during the cooling following tempering (producing the so-called secondary quench, *trempe secondaire*.) The tempering of martensite consists of a progressive decarburization of the alpha iron + carbon solution, spread over a wide temperature interval. In the tempering of quenched steels these reactions occur concurrently.

In collaboration with P. Benazet, I myself studied a steel containing 0.35% C, 2.0% Si, 12.0% Cr, 7.0% Ni — a composition nearly identical with that used by Mr. Friedmann — and showed that it contracted during a prolonged holding between 725 and 925° C. (1350 and 1700° F.), a manifestation of carbide precipitation. When the steel was cooled there was a pronounced expansion at about 300° C. (575° F.), a manifestation of the martensitic transformation with the appearance of ferromagnetism and an increase in hardness. The same sample on being reheated contracted at about 600° C. (1100° F.), the Ac_1 point, returning the steel to the austenitic state.

This steel is not in stable equilibrium at room temperature when in the austenitic state. It is held in this state by the strong passivity toward transformation (*résistances passives*) caused by the presence of carbon in solution. When part of this carbon is precipitated, the passive resistance diminishes and the austenite, more unstable, can then transform when supercooled to low temperature. This high nickel-chromium steel, when quenched from high temperature and thus in a fairly stable austenitic state, must be reheated several hours between 725 and 925° C. (1350 and 1700° F.) to precipitate sufficient carbide to permit the martensitic transformation on cooling.

A study of steels much lower in special alloy content reveals different phenomena. We have also studied a steel containing 1.05% C, 0.20% Si, 0.12% Mn, 5.93% Cr, and 0.09% Ni quenched from 1250° C. (2300° F.) — a treatment rendering the steel completely austenitic. On heating such an austenitic sample, one can observe a contraction as the temperature passes 550° C. (1025° F.) indicative of carbide precipitation; this precipitation, however, sufficiently diminishes the passive resistance to the gamma → alpha transformation that the specimen suddenly expands.



Dilatometer Curves Taken During the Reheating of Quenched (Austenitic) Chromium-Nickel Steel. Carbide precipitates on heating at a_1 and on holding at a lower temperature at a_2. If the temperature is not raised to the allotropic transformation at b, it occurs at a low temperature c_1 or c_2 on cooling

with recalescence, at about 600° C. (1100° F.) thus returning the steel to the alpha state, as shown by the coefficient of contraction on cooling and the recovery of magnetism. The course of such an experiment is shown in the first curve, derived by a Chevenard dilatometer. If the heating is stopped after the contraction has set in, but before the sudden dilation (Curve 2), and the sample cooled without delay, a pronounced expansion due to the appearance of martensite starts at 150° C. (300° F.). This constitutes the phenomenon of secondary quenching noted by Chevenard and Portevin in their 1930 publication first quoted.

Carbide can be precipitated from austenite in this 6% Cr steel at somewhat lower temperature than 1100° F. if the steel is held, say, four hours (see Curve 3). These observations have been recorded in *Revue de Métallurgie* in 1929, p. 463, and 1930, p. 501.

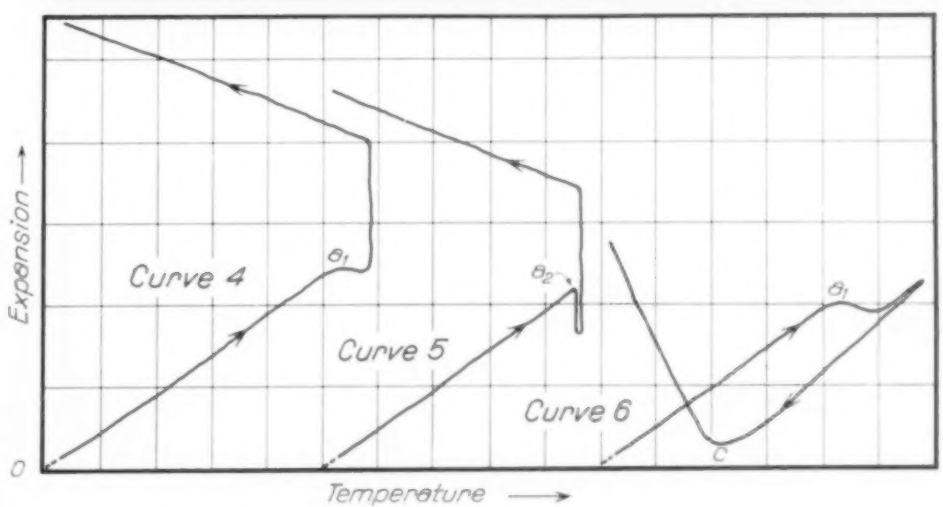
For those steels which can only be made austenitic at room temperature by hyper-quenching, the gamma → alpha transformation can be produced in various ways following a precipitation of carbides. This precipitation may be so rapid as to be completed totally during mere heating at a moderate rate; on the other hand, it may be so slow as to require a rather prolonged soak at a certain temperature. If it occurs when normal heating reaches a certain temperature, a prolonged holding at a somewhat lower temperature will cause it to progress at a rate proportionately slower as the temperature is lower.

When the carbide does precipitate, the passive resistance to the gamma → alpha transformation is diminished so much that it can take place in one of the following forms:

1. If the passive resistance is small, transformation occurs almost instantly by trigger action at a certain rising temperature slightly above a_1. This is shown by Curve 4.

2. If, in the case cited above, heating is stopped before point a_1 and the temperature held, carbides begin to precipitate at a_2 causing an isothermal contraction; the gamma → alpha transformation then begins and as it continues causes a gradual isothermal dilation, the rate depending on the temperature (Curve 5).

3. If the passive resistance of the steel pre-



Three Modes of Transformation of Austenite. Curve 4: Carbide precipitates at a_1 and at a somewhat higher temperature austenite transforms almost instantly. Curve 5: Carbide precipitates during long anneal at a_2 and austenite transforms in course of time. Curve 6: If time at a_1 is insufficient, residual austenite transforms (at least in part) at low temperature c—the secondary quench

vents a sudden, almost explosive transformation, it takes place as in Curve 4, but is gradual over a more or less prolonged stay at temperature. However, if sufficient time is not allowed for it to occur, it will take place on cooling at low temperature, thus constituting the secondary quench (*c* on Curve 6).

This last mode of transformation is the only one that is encountered when carbide precipitates at a temperature higher than the Ac point of the steel, since austenite is there the stable phase.

We have already published two papers concerning an extended investigation of variations in the mode of transformation as a function of the composition with particular reference to high speed steels (*Revue de Métallurgie*, 1930 and 1932, p. 501 and 259 respectively).

André Michel
Assistant Technical Director
Etablissements Jacob Holtzer

Advantages of Bakelite For Mounting Small Specimens

Harvey, *Ill.* — Authorities on metallography, including the ASMetal Handbook, recommend that small specimens be mounted in a fusible alloy prior to polishing and etching, and this method with all its drawbacks is used in many laboratories. However, others have installed equipment — some of it homemade — for mounting specimens in a plastic compound like bakelite. The present writer has used the latter method, in the laboratory of Bliss & Laughlin, Inc., for many hundred samples, and cannot recommend it too highly; bakelite has good resistance to reagents, adheres excellently to the specimens, and eliminates margins, crevices and relief polish.

Small hydraulic presses, with heater and molding tools which are now available, are neat, compact and simple to operate. The bakelite mold is in three pieces, a base on which the sample or samples are placed, a surrounding cylinder, and a tight-fitting plunger. Bakelite powder is poured into the cylinder in appropriate amount to cover the specimen and hydraulic pressure forces the plunger down compressing the material. An electric heater, placed about the mold, gradually brings the temperature up to the curing point; pressure is maintained at all times until the process is complete. At the end a button of material is ejected. The whole process is fast, clean and simple to operate and always gives the same size sample, which is smooth and shiny and very neat as well as easy to store for future reference.

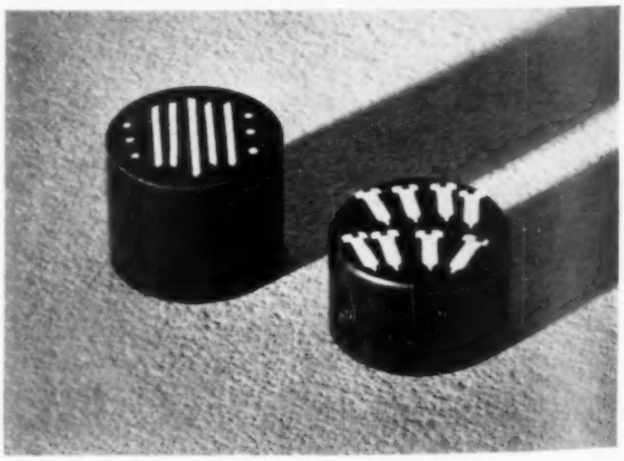
In polishing such a sample as illustrated, no abrasive lodges between the sample and the mount since the bakelite adheres closely to the metal. There is no danger of relief polishing and the uniform size and shape of the mount insures constant pressure at the wheel and more uniformly polished samples. Their shape is convenient to handle and a standardized routine can be developed for grinding and polishing.

Wire, sheet, small tubes and very small sections of larger samples can be polished and examined with no difficulty. The powdered bakelite will maintain the samples erect and properly positioned until the temperature is raised sufficiently, at which time both the plastic bakelite and the pressure keep them in the proper position.

Since there is no danger of injuring the section to be inspected, it is necessary to mount only the required part, which saves time because a very large sample naturally requires more time to polish than does a small sample. Furthermore, it is not necessary to hold the smaller samples on the wheels as long, which avoids the danger of polishing pits, an especially important feature when examining unetched sections.

Probably the greatest satisfaction will be had when it is necessary to examine a specimen at the very edge of the polished area. Soft metal mountings are wholly incapable of maintaining such edges, whereas bakelite polishes down uniformly with the metal to a smooth surface, resistant to all the common etching reagents.

F. L. Robbins



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Solubility of Carbon in Ferrite

By J. H. Whitely

Condensed from Journal of the Iron & Steel Institute

Three points in the iron-carbide diagram relating to a carbon content less than 0.10% have been generally accepted. Point *N*, which indicates the solubility of carbon in alpha iron at room temperature, was fixed by T. D. Yensen at 0.008%. Point *D* represents the solubility at Ar_1; it is here placed at 0.03%, as was first deduced by Howard Scott from cooling curves and subsequently confirmed in other ways by several workers. Point *G* is the Ar_3 point for pure iron. These three points having been fixed, an attempt is made in the present paper to delineate the curvatures of the lines joining them.

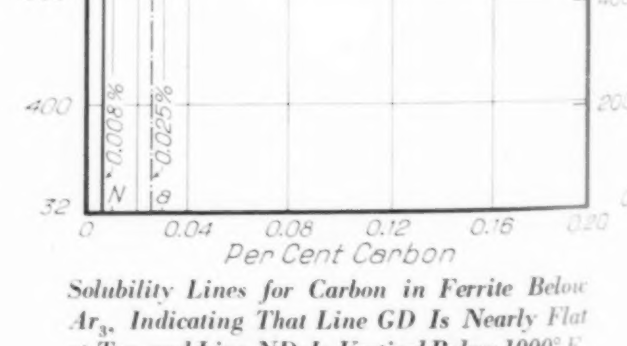
Armco iron having 0.025% carbon and 0.004% nitrogen was the principal material used, although identical results were secured with extremely pure iron slightly carburized in charcoal, electrolytic iron sheet free of nitrogen carburized to 0.10% carbon and then almost completely decarburized in hydrogen, and with carbonyl iron containing 0.015% carbon. For micro examination after definite heat treatments the specimens were polished and then etched by a special technique. The reagent used was the very sensitive Le Chatelier and Dupuy's cupric reagent containing: Alcohol (95%) 100 cc., water 10 cc., copper chloride 1 g., picric acid 0.5 g., hydrochloric acid 1 to 3 cc. Indications of this reagent were checked by examination after etching with picric acid, nitric acid or sodium picrate.

When specimens of the Armco iron were examined, a definite constituent was invariably to be seen at the grain boundaries. It was subsequently found that there could be little doubt that this constituent was cementite in the form of boundary films.

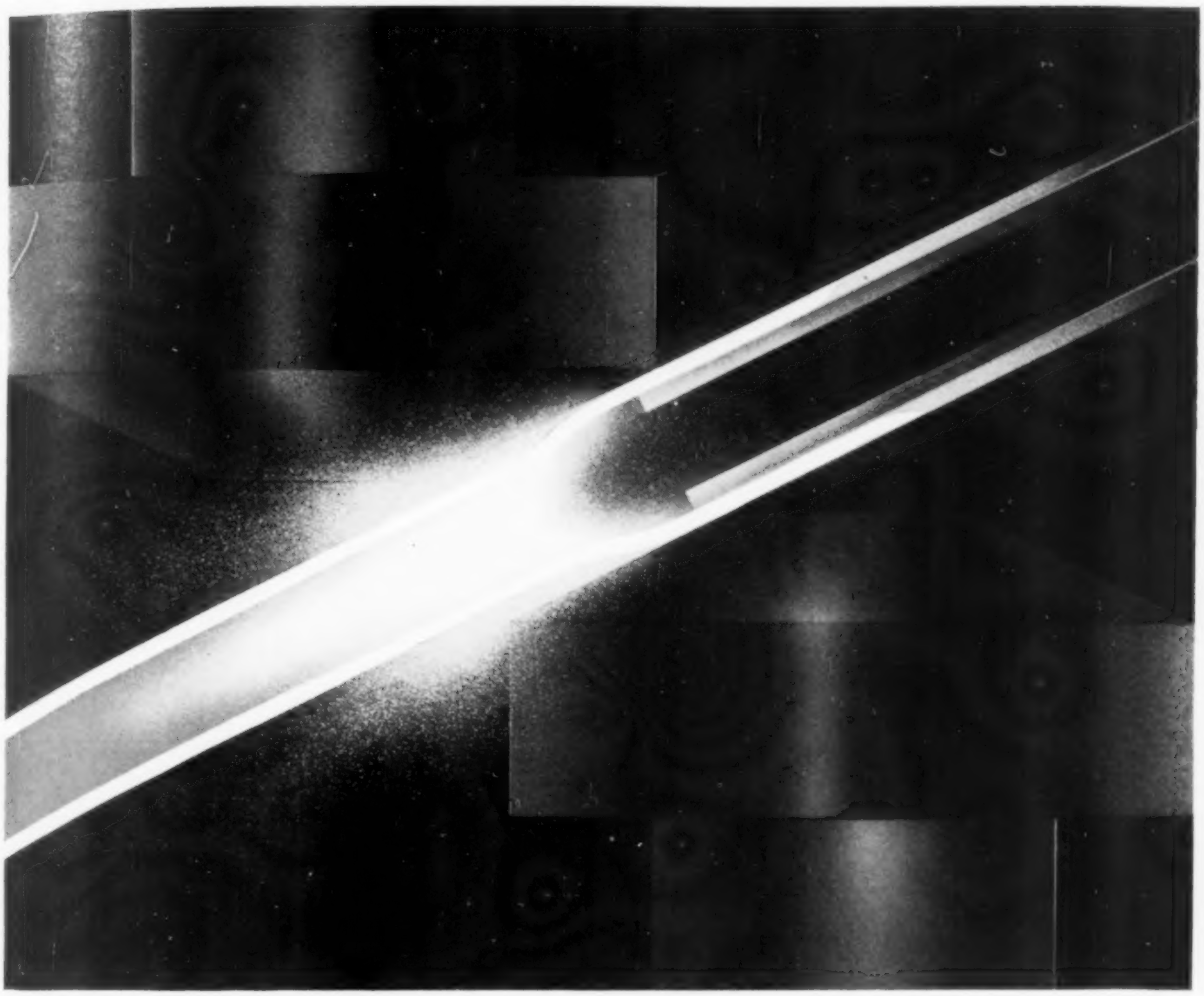
Specimens of the Armco iron were heated to different temperatures, quenched in water and examined. Up to 1020° F. (550° C.) no reduction in the quantity of cementite was noticeable even after heating for 1 hr. Above 1020° F., however, the cementite crystals began to diminish gradually in size and number until at 1255° F. (680° C.) no trace of them remained. It was repeatedly found that saturation of the ferrite with carbon was reached with remarkable rapidity. Three minutes' heating, which included the time—about 2 min.—required to bring the specimen to the temperature, was, as far as could be judged, sufficient in all cases to lessen the amount of visible carbide to the same extent as heating for 1 hr.

The above observations are in agreement with deductions of Köster by making use of the Eggertz color test for carbon. Thus both microscopic and chemical methods of inquiry indicate that there is no appreciable increase in the solubility of carbide in alpha iron below about 1020° F. (550° C.) which means that the line *ND* must be drawn vertically to that temperature.

As previously stated, no carbide was visible in specimens quenched from about 1255° F. (680° C.). On raising the temperature of quenching, this completely ferritic structure persisted until 1510° F. (820° C.) was reached, when a few scattered areas of martensite were observed. As the temperature was raised still further, these areas grew in size and number. *(See page 88)*



Solubility Lines for Carbon in Ferrite Below Ar_3, Indicating That Line GD Is Nearly Flat at Top and Line ND Is Vertical Below 1000° F.



Rolling and Annealing of Steel Sheet

By C. A. Edwards, D. L. Phillips and W. H. E. Gullick

Condensed from Journal, Iron & Steel Institute

IT HAS long been known that the crystal size in metal depends upon the degree of cold work and on time and temperature of subsequent anneal. Quantitative measurements on iron show that the original grain size is also important — the larger the initial crystals in the material, the greater is the critical strain required in order to produce the maximum crystal size, and the size of the crystals obtained after straining and annealing is less as the initial crystal size increases. In ferrite crystals in steel these effects, occurring at temperatures below the transformation, are interrupted by recrystallization at Ac_1 when alpha iron passes into the gamma form.

These large crystals are to be avoided in commercial sheets, and the present investigation was planned to study the influence of mill variables on the softness of 0.013-in. sheets as measured by the Erichsen cupping test.

In the first place some samples were annealed 1 hr. at several temperatures between 950 and 1750° F. They had previously been cold rolled to the extent of 100% elongation. The results were compared with the corresponding data for the same material which had been hot rolled to the desired thickness. Prior to cold rolling, those sheets that were submitted to this operation were normalized in a commercial normalizing furnace and, therefore, possessed the usual small-grained, equi-axed structure. In the case of the hot rolled material, a negligible amount of softening takes place after annealing at temperatures up to 1200° F. This is followed by a sharp rise in the Erichsen value at 1300° F., after which the improvement is less rapid. With the heavily cold rolled samples, however, the steel becomes as soft after annealing at 1000° F. as the hot rolled material is after annealing at 1300° F. Further, this superiority of the cold rolled samples for any specific annealing temperature is maintained throughout.

In the hot rolled material, what can be conveniently described as recrystallization does not occur at temperatures below the Ac_3 point, while after heavy cold rolling recrystallization commences at 1025° F., and is complete after annealing at any higher temperature. Needless to say, recrystallization again takes place at the Ac_3 point, but the structure obtained is practically the same as that which results from the recrystallizations by annealing heavily cold rolled steel at about 1300° F.

Next the influence of time (½ hr., 1 hr. and 5 hr.) of annealing at different temperatures was studied, and it was found that results were very similar for various degrees of cold rolling — namely, that 5 hr. at 1000° F. softened the metal to the same Erichsen value as ½ hr. at 1150° F. However, at temperatures above 1200° F. the effect of time after 1 hr. is rather small.

A similar family of curves results when the Erichsen value is plotted against annealing temperature and the third variable is degree of cold rolling of sheets which had been hot rolled but not annealed or normalized. From the practical point of view, perhaps the most interesting feature revealed by these last-mentioned experiments is that by giving the steel a 10% elongation by cold rolling, without previous annealing, the values obtained by annealing between 1200 and 1400° F. subsequent to cold rolling are extremely good and, indeed, practically equal to those that are obtained by completely annealing or normalizing hot rolled material that has not been subjected to any cold rolling.

We then tried to find what, if any, effect the original condition of the material — as influenced by two different methods of annealing prior to the cold rolling operation, that is, pot annealing versus normalizing — has upon the properties of cold rolled and subsequently annealed sheets. As is perhaps well known, in pot annealing, the weight of material in each pot is relatively large, and in consequence a long time is required to reach the annealing temperature and the material has to be maintained above, say, 1300° F. for a prolonged period. Further, under normal conditions, the temperature attained is definitely below the A_3 change point; for these reasons the microstructure parallel with

(Continued on page 84)

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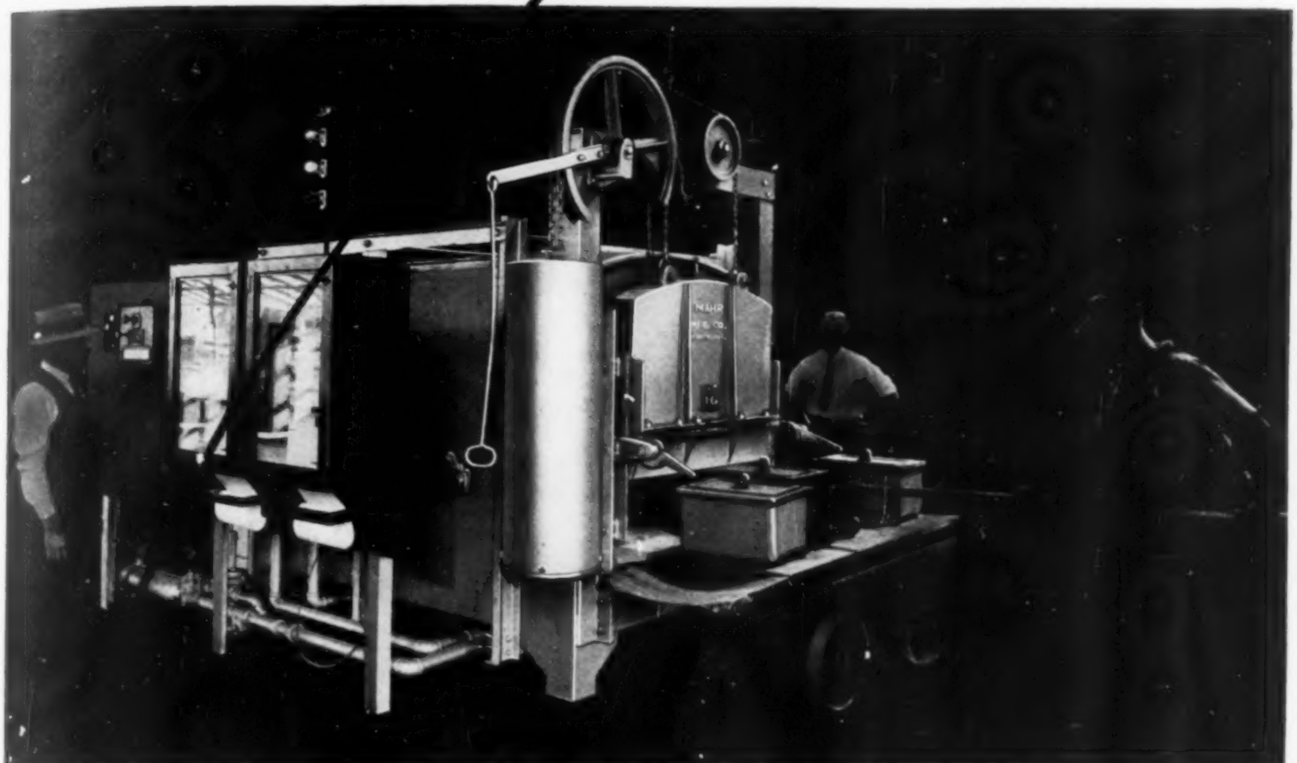

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Personals

Ancel St. John, St. John X-Ray Service Inc., is recovering from a concussion which laid him up for 18 months.

Oscar O. Miller has joined the staff of Mellon Institute of Industrial Research, Pittsburgh, as industrial fellow.

Harry Hardwicke has been appointed district manager of Latrobe Electric Steel Co. in Chicago.

Norman E. Woldman, formerly with the United States Navy, is now chief metallurgist and vice-president of Eclipse Aviation Corp.

Roy G. Roshong has been appointed metallurgist of Lindberg Steel Treating Co., Chicago.

Albert L. Marsh, president, Hoskins Mfg. Co., Detroit, was awarded the John Price Wetherill Medal of the Franklin Institute for "contribution of a material of extreme importance to the electrical industries." The Edward Longstreth Medal of the Institute was awarded to **Alfred V. deForest,** president, Magnaflux Corp., and **William E. Hoke,** consulting engineer, Baltimore, for the development of a "ready means of detection of hidden defects." **George O. Curme, Jr.,** was the recipient of the Elliott Cresson Medal, for the development of synthetic aliphatic compounds.

Charles E. Kraus has joined the Ingersoll Milling Machine Co. to do research primarily in metal cutting.

F. Hall Hately is product development engineer with Scovill Mfg. Co.

Wm. G. Hassel has been appointed sales and development engineer for Pittsburgh Crucible Steel Co.

George J. Moeller has been made production manager of Dazey Churn Mfg. Co., St. Louis, Mo.

David McLain has been awarded the J. H. Whiting Medal of the American Foundrymen's Association.

Haig Solakian has accepted a position as research metallurgist for A. F. Holden Co.

Stanley A. Knisely, formerly manager of the Advertising and Sales Promotion Division of Republic Steel Corp., has been appointed director of advertising. **Forrest H. Ramage** has been promoted to the position of sales promotion manager, and **Chester W. Ruth** to assistant director of advertising.

Lewis S. Reid is now technician in the Standardization Laboratory of Metropolitan Life Insurance Co., New York.

Neil Metcalf is metallurgist for Burlington Steel Co., Ltd., Hamilton, Ont., Canada.

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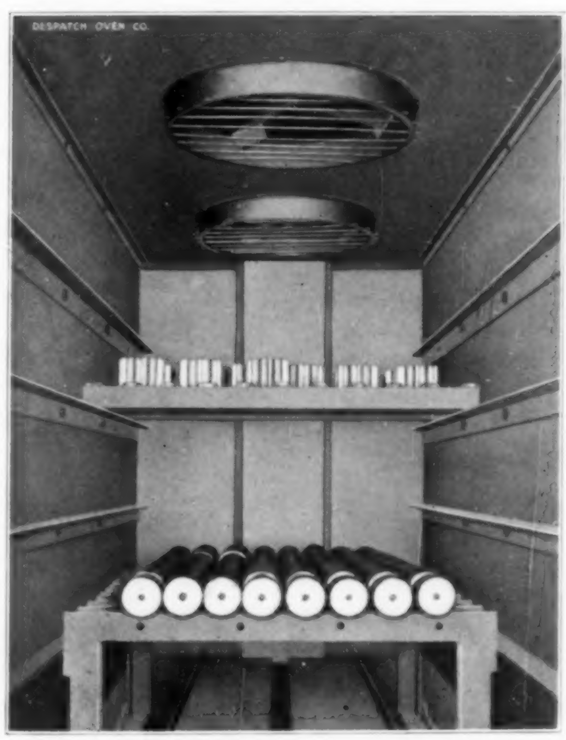

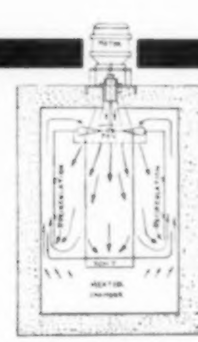

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Personals

Bradley Stoughton, head of Lehigh University's Metallurgy Department, has been appointed dean of engineering, a position newly created.

George O. O'Hara has joined the sales department of the Detroit Electric Furnace Co.

John Dolza, designing engineer for the past two years at Buick Motor Co., has been made assistant chief engineer.

C. R. Cox has been elected vice-president in charge of operations and engineering for National Tube Co., Pittsburgh.

L. W. Grothaus, assistant to the president, Allis-Chalmers Mfg. Co., Milwaukee, has been elected a director of the company.

Robert J. McKay, of International Nickel Co., has been elected a member of the Executive Committee of the American Section of the Society of Chemical Industry.

A. W. Demmler has been appointed metallurgical engineer in the Research & Development Department, Vanadium Corp. of America, Bridgeville, Pa.

Walter E. Peterson has been transferred to the new plant of Greenfield Tap and Die Corp. at Detroit, the former Carpenter Tap and Die Co., and will serve as chemist and metallurgist of this division.

George A. Nelson is now metallurgist for Shell Chemical Co., Shell Point, Calif.

Ray C. Skeel, formerly with the Pressed Steel Division in Cleveland, has been transferred to the Truscon Steel Co. at Youngstown as plant engineer.

L. E. Mustard has been appointed district manager of the Bristol Co. in Detroit.

J. W. Braffett has joined the sales staff of Republic Steel Corp., Upson Nut Division, in Detroit.

Sol Einstein, formerly chief engineer, has been made a vice-president of the Cincinnati Milling Machine Co.

Joseph L. Block has been named executive vice-president in charge of sales, and **Albert C. Roeth** vice-president and general manager of sales for Inland Steel Co.

E. F. Entwisle has been appointed assistant general manager of the Lackawanna plant of Bethlehem Steel Co., and **J. M. Sylvester** has been made assistant general manager of the Bethlehem plant. **V. J. Pazzetti** is superintendent of the Saucon Division of Bethlehem and **J. C. MacNeil** superintendent of open-hearths, Saucon Division.

Emil C. Traner is new president of the Mechanics Universal Joint Division of Borg-Warner Corp. at Rockford, Ill.